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Efficiency Tests of Tractor Wheels and Tracks[1]

By E. V. Collins[2]

FOR A NUMBER of years we have been making efficiency studies of tractor tracks and wheel equipment at Iowa State College, with the aid of our graduate students, and I am glad to share any credit for this work with Dr. J. B. Davidson and E. G. McKibben of our staff, the Caterpillar Tractor Company and the U.S.D.A. Bureau of Agricultural Engineering for furnishing tractors for the tests, and to B. T. Virtue, G. D. Kite, I. L. Williams, and Ben Van Zee for their work as graduate students.

It has been our aim in this work to secure some fundamental information regarding the performance of tractor tracks and wheels over their normal working range based upon the efficiency of the wheel or track unit itself as a means of converting power from the final drive shaft to the drawbar.

Tests with Tractor Tracks. The equipment used for these tests consisted of a Caterpillar "20" tractor with a recording and integrating dynamometer built into the front support for the engine and transmission which are of unit construction. This dynamometer measured the weight carried at this point. This particular model tractor has its track frames pivoted on the same centers as the drive sprockets. When the tractor is in operation, the torque applied to the rear axle tends to lift the front end of the engine, and this tendency to lift is proportional to the torque applied to the sprocket. For normal operation the hitch is attached to the rear of the transmission, but as this type of hitch would produce a separate torque, the regular hitch was removed and one attached to the two tracks frames was substituted.

The dynamometer car used for providing a load for these tests has a pair of guide wheels in front and tracks in the rear. A large rotary pump which provides the necessary resistance to travel is geared to the tracks. The valve of the pump is operated automatically to provide a constant drawbar pull. The hitch is connected directly to a large piston working against oil pressure provided by a second pump. A relief valve set to give the desired pressure on the piston by-passes the surplus oil back to a reservoir. In this way a constant pressure is maintained on the piston attached to the hitch, and the piston is kept near the center of its travel by having it connected to the valve on the large resistance pump, so that if the piston moves toward the front of its travel, the valve will be opened and lower the resistance of the car. If the piston moves backward the valve is closed to increase the resistance.

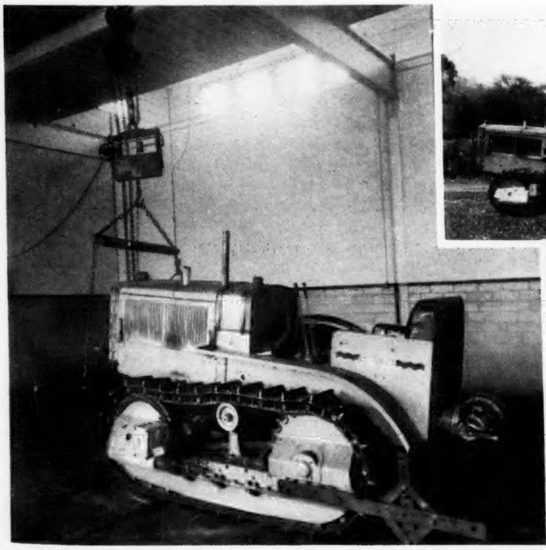
Test Methods. The methods of conducting the tests and the observations made were as follows:

1. Each test represents an average for 50 ft of travel after equipment is in motion.

2. Each test was repeated and in case the results did not check further tests were made.

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers held at The Stevens, Chicago, November 1932.

[2]Research professor, department of agricultural engineering, Iowa State College. Mem. A.S.A.E.



Three views of the equipment used in the Iowa efficiency tests of tractor wheels and tracks. Fig 1 (Left) This shows the dynamometer attached to the front spring of the tractor, the crane scales supporting the front end for calibrating, and the special hitch attached to the track frame. Fig 2. (Upper right) The Caterpillar tractor under test. Fig 3 (Lower right) The John Deere tractor under test

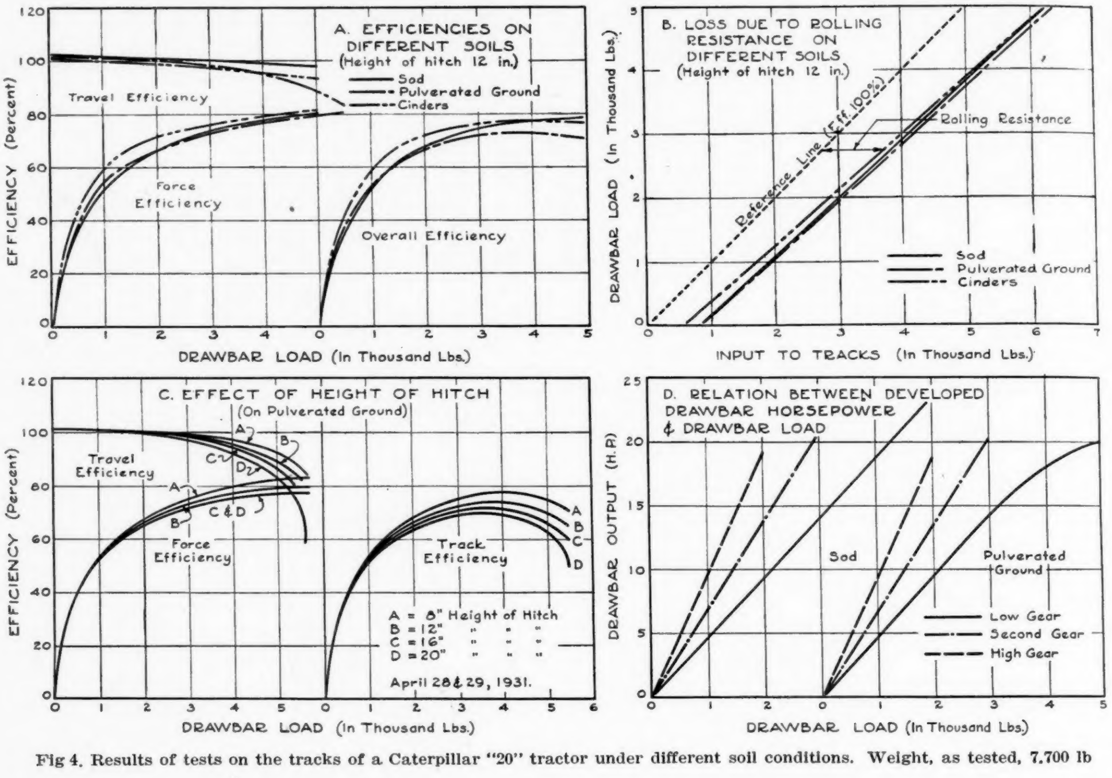


Fig 4. Results of tests on the tracks of a Caterpillar "20" tractor under different soil conditions. Weight, as tested, 7.700 lb

3. The input dynamometer was calibrated on the basis of pounds force applied at the track. The radius used was that of a circle with a circumference equal to 12½ track links. [(12½ x 6.735) ÷ (2 x 3.1416) = 13.4 in]. The term "force efficiency" is used to represent the relation between the force applied to the tracks and drawbar pull exerted on the dynamometer car. The center of gravity of the engine and transmission unit is higher than the driveshaft, and it was found that an appreciable error would result if the angle which the frame makes with the horizontal varied much from that at which the calibration was made. On account of this it was necessary to record the angle of the engine frame for each test and make corrections where necessary.

4. The term "travel efficiency" is used to represent the relation between the distance actually traveled and the distance it would have gone based on the track length. (29 x 6.735) ÷ 12 = 16.275 ft. Stakes were set beside a marked link and a mark on the track frame for each revolution of the track. Then, by means of a steel tape, graduated so that 100 units is equal to twice the length of the track, the percentage or efficiency of travel was read directly by holding the zero end of the tape at one stake and reading at the second stake. Two readings were made for each test.

5. The term "overall efficiency" is the product of the other two efficiencies and represents the efficiency of the track unit as normally loaded for converting work or power at the driving axle into drawbar work or power.

In making these tests no particular effort was made to secure the maximum drawbar output from the tractors but rather to determine the relationships which may be expected in normal operation.

Discussion of Results. The efficiency curves for different soil conditions (Fig 4A) represent the performance of the tracks under a range of conditions which might be expected in field operations and shows surprising uniformity for the conditions tested.

The force curves (Fig 4B) for the same tests show graphically the losses due to friction and rolling resistance for various loads and soils.

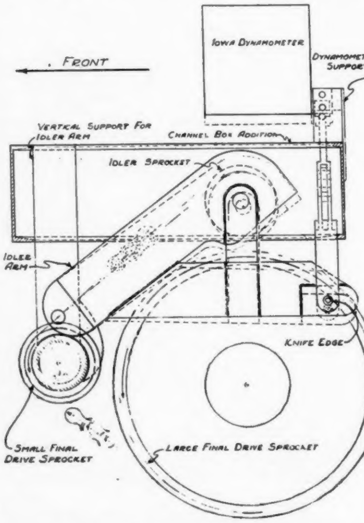


Fig 5. Arrangement on John Deere tractor to measure tension of drive chain

The efficiency curves for four different heights of hitches for "pulverated" soil (Fig 4C) show the advantage of a low hitch. This held true for all conditions tested except hard cinders where the 12-in hitch gave the best results. Perhaps in this case more penetration of the hard surface was secured by tilting the tracks up slightly.

Fig 4D shows the relation between drawbar load and gear and drawbar horsepower output for different gears.

Other tests made indicated that used tracks had less friction than new ones (the tests here reported being made with used tracks), that at least half the rolling resistance would be saved if the track were laid out for it instead of having to pick up and relay its own track.

Tests with Tractor Wheels. The equipment used in these tests differs only in the tractor and type of input dynamometer used. A John Deere "Model D" tractor was selected be-

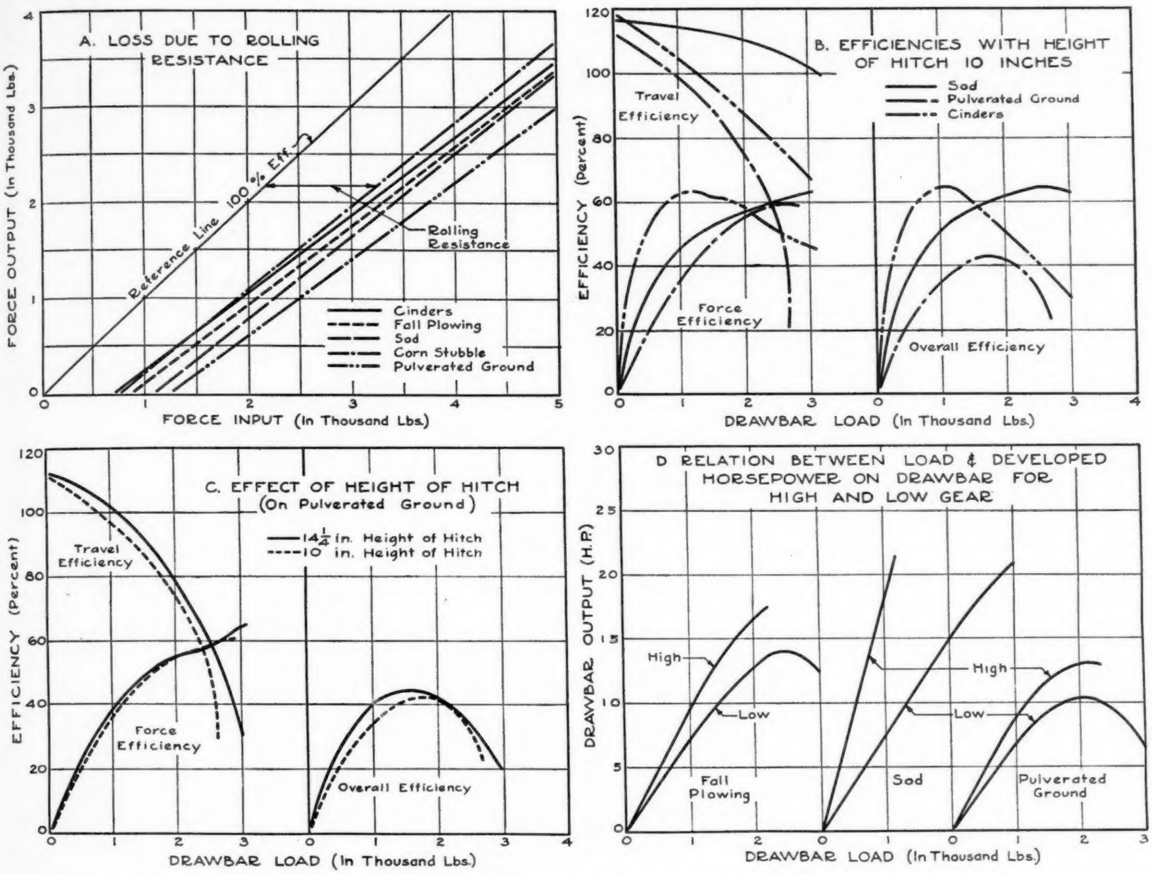


Fig 6. Results of tests on the wheels of a John Deere "Model D" tractor under different soil conditions. The wheels were of the standard type with 5-in spade lugs. Weight, as tested, 4,730 lb—1320 lb on front wheels and 3,410 lb on rear wheels

cause the design of the final chain drive appeared to offer an excellent opportunity to attach an input measuring device. In this case an integrating dynamometer was used to measure the tension in one of the final drive chains. An idler sprocket was mounted on a swinging arm above the large driven sprocket and connected by linkage to the dynamometer (See Fig 5.) Calibration was made on the basis of force applied to the rim of the drivewheel either 21 or 23-in radius depending upon the wheel used. It is admitted that the effective diameter of the wheels is larger, but there seems no other satisfactory basis for making such tests, where soil conditions vary so much. As the travel efficiency is also based on the circumference of the rim, the overall efficiency would be the same regardless of wheel diameter assumed.

In these tests on tractor wheels no attempt has been

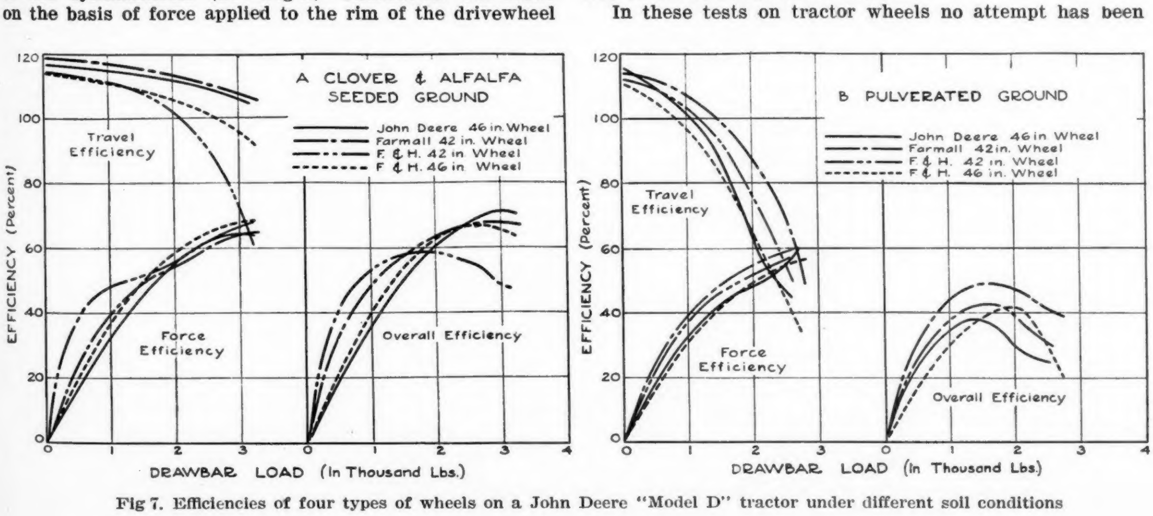


Fig 7. Efficiencies of four types of wheels on a John Deere "Model D" tractor under different soil conditions

made to separate the power required to propel the front wheels as they would appear to be a necessary burden to the drivewheels. With this tractor the weight is often removed from the front axle when using the higher hitches and larger loads. The height of hitches given in Fig 6C represents the height as measured on a level floor based on the wheel rim. In operation this hitch becomes lower due to the tendency of the tractor to rise in front.

The graphs (Fig 6) were made from tests with John Deere tractor with 46-by-11-in wheels and 5-in spade lugs: Force curve, Fig 6A, shows the rolling resistance for a variety of soils as affected by the load. Efficiency curve (Fig 6B) compares the efficiency factors for three soil conditions. Very distinct differences will be noted. Efficiency curve (Fig 6C) compares two heights of hitch. As would be expected the higher hitch gives best results as more weight is transferred from the front wheels to the drivewheels.

The French & Hecht Company have furnished us with two sets of open wheels which we can use on this tractor, 42 and 46-in rim and the same hub flanges will take the F30 Farmall wheels 42 by 11 in with 5-in spade lugs. We have made two sets of tests comparing the four types of wheels. These were all made the same day and as nearly as practicable under the same conditions. The French & Hecht wheels were used only in skeleton form.

It is interesting to note in the curves for sweet clover and alfalfa seeding (Fig 7A) a complete reversal of the order of the wheels as the load increased. Two days before this test we were plowing in the sweet clover with the F30 and three 14-in bottoms and stalled due to lack of traction for the wheel on the land. By substituting the French & Hecht open wheel on this one side, no further difficulty was encountered. We expected to secure the test comparisons for these conditions, but it had dried enough so that none of the wheels tested filled up. The "pulverated" ground was loose, too deep (about 9 in) for the open wheels to cut through to solid ground. As no tests were made under soil conditions for which the open wheel was particularly adapted, it should be emphasized that these curves (Fig 7) do not represent a complete comparison of the four wheels but rather a sample of results which may be secured.

The Firestone Tire & Rubber Company and the French & Hecht Company are furnishing us pneumatic equipment for this dynamometer-equipped tractor and we are looking forward to their test with a great deal of interest.

An Ice-Chilled Meat Curing Box for Farm Use

By T. A. H. Miller[1]

An unusual type of ice box[2] for use in curing meat on southern farms has been designed and tested by the Bureau of Agricultural Engineering and the Bureau of Animal Industry, of the U. S. Department of Agriculture.

Tests have shown that an inside temperature of 36 deg F can be readily obtained and held when the outside temperature is 70 to 80 deg.

As shown by the accompanying illustrations the walls of the box are of 2-by-4-in lumber, laid like the crib-work of a granary, lined inside with galvanized metal, and insulated on the outside with 7 in of sawdust held in place with a casing of tongued-and-grooved ceiling. The bottom is of concrete insulated with 4 in of cork. Inside of the box is a slatted floor and two slatted sides with a metal top to form a removable crate. The meat to be cured is placed inside the crate and ice in blocks or pieces is placed between the crate and box walls and on the metal top. The sides of the crate are so constructed as to permit circulation of air.

Access to the box is by means of a hinged lid, making it necessary to climb into the box for filling and icing. This type of structure, though more inconvenient than the walk-in boxes with overhead or side bunkers was selected because (1) it is lower in cost; (2) inexperienced workmen can build it; (3) most of the materials are readily available; (4) ice consumption is less, and (5) desirable temperatures below 40 deg cannot be obtained in overhead boxes with ice alone.

The box has a capacity of 1,800 to 2,000 lb of meat and 1,600 lb of ice. The length and height can be increased or lessened to meet individual needs but the width should not be increased. If built 9 or 12 ft long, space would be available for curing meat from twenty-five or thirty-five 200-lb hogs thus making it adaptable to community use.

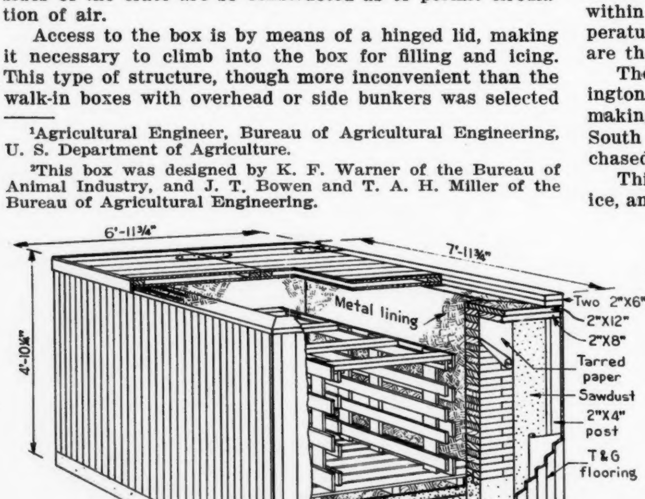
Prompt cooling is essential to prevent spoilage of the meat. Because of the time required to cool the meat in the box it is recommended that, if possible, freshly slaughtered carcasses be hung in the air or immersed in barrels of iced weak brine and chilled to a temperature of about 36 deg before placing in the box. By shifting the chilling meat frequently in the brine and adding more ice when necessary a temperature below 40 deg should be secured within 24 h. The time required will depend upon the temperature maintained and the size of cuts. The chilled cuts are then salted and packed in the box for curing.

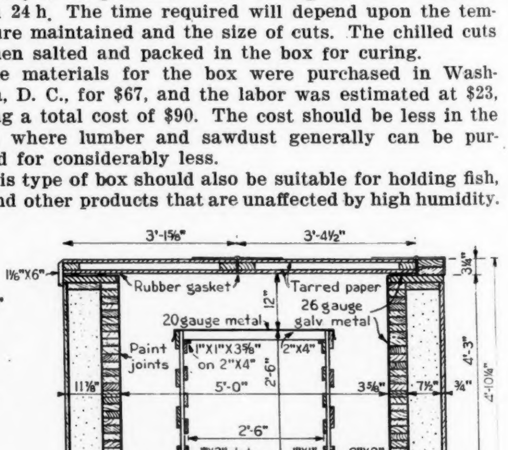
The materials for the box were purchased in Washington, D. C., for $67, and the labor was estimated at $23, making a total cost of $90. The cost should be less in the South where lumber and sawdust generally can be purchased for considerably less.

This type of box should also be suitable for holding fish, ice, and other products that are unaffected by high humidity.

[1]Agricultural Engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture.

[2]This box was designed by K. F. Warner of the Bureau of Animal Industry, and J. T. Bowen and T. A. H. Miller of the Bureau of Agricultural Engineering.



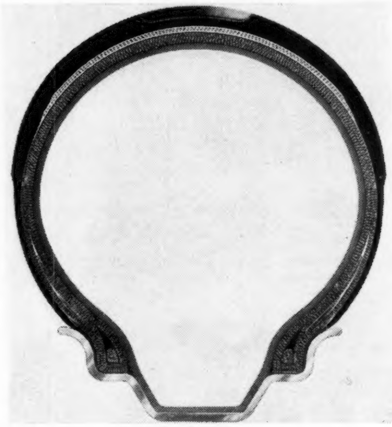


Perspective and section views of an ice-chilled meat curing box especially designed for farms of the South

Pneumatic Tires for Agricultural Tractors[1]

By J. W. Shields[2]

THE idea of using rubber tires on tractors is not new. Both solid and pneumatic tires have been sold as regular equipment on industrial machines for years, and there have been many attempts to use either these same types or other specially designed tires on farm tractors, but it was not until within the past year that a special low-pressure pneumatic tire was developed, which has proven practical for farm operation. The performance of this tire is outstanding, and it may replace steel wheel and lug equipment in a large majority of farm operations. Also it has possibilities of completely revolutionizing both tractor and farm implement design.



Cross section of a tractor rubber tire mounted on a standard drop-center rim

Farm tractors, when equipped with these tires, will no longer be limited to a narrow field of operation, but will become general-utility machines to be used wherever power is required. They will no longer be barred from the highways, and when equipped with higher speeds for road operations will, without doubt, be used to haul rubber-equipped trailers and farm wagons, eliminating the necessity for either trucks or horses on the average farm. The higher operating speeds made practical by pneumatic tires will, without question, be reflected in a redesign of all types of farm machinery, with changes to provide for the increased speeds.

The principal function of tires on trucks and busses is to carry a heavy load and absorb road shocks, to protect the vehicle from jolts and jars. On tractors the chief function of the tires is to provide traction for the heavy drawbar pull required for field operation. Because of this wide variation in the requirements for the two types of service, it is only logical that the two tires should be essentially different in construction. A truck or bus balloon tire of the same general dimension as the tire used on the two to three-plow tractor has 14 piles of cord fabric. The tractor tire has only six. The truck tire carries 80 lb of air pressure, the tractor tire only 12 lb. The truck tire has a carrying capacity of 6050 lb; the tractor tire is rated at 2000 lb.

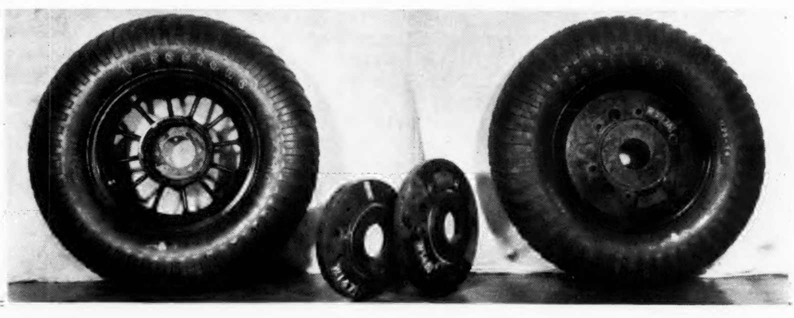
The real success of these tires can be attributed to the very low air pressure carried and the resulting large area of contact they make with the ground. Twelve pounds of air pressure is recommended for the rear tires for ordinary farm operation. The tire used on the two to three-plow tractors with 12 pounds pressure, and under rated load, flattens out until it makes a contact with the ground 19½ in long and 9½ in wide, with an area of 150 sq in. It is this large area of contact that provides the traction which can be secured with steel wheels only by using lugs to cut into the ground. The thin, flexible construction of the tire permits it to bend and conform to the irregularities of the ground and therefore exert a uniform pressure and tractive effort over the entire area of contact.

The question of adequate traction is the first one raised regarding the operation of these tires. At first it seems incredible that a rubber tire with a comparatively shallow tread design could provide traction comparable with that of steel wheels which have lugs to penetrate 5 or 6 in into the ground. Experience, however, has proven that the pneumatic tires do provide ample traction for operations encountered in farm work under ordinary conditions. A great many tests over a wide range of soils and operations have demonstrated that for conditions encountered on the average farm, a tractor equipped with rubber tires will almost without exception develop a greater drawbar pull than the same tractor with the standard steel wheel and lug equipment. I do not wish to be understood as claiming that under any and all exceptional conditions the rubber tires will outpull steel wheel and lug equipment; we know that there will be many special cases, such as mud, snow, or ice, when chains will be required just as they are on trucks or passenger cars. A complete season of testing many of these tires over a wide variety of farm operations and soil conditions in several different states has demonstrated that the tires have adequate traction for all ordinary operations and their many other advantages more than offset the few cases where steel wheels might provide better traction.

The traction developed by a pneumatic tire bears a direct relation to the load it carries. As the load is increased the tire flattens out making a larger area of contact with the ground and therefore develops greater traction. The accompanying chart shows the relation between the drawbar pull and the weight on the tires. It has been found that it is necessary to have about 400 to 500 lb extra weight per wheel to secure the required traction for a

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers held at The Stevens, Chicago, November 1932.

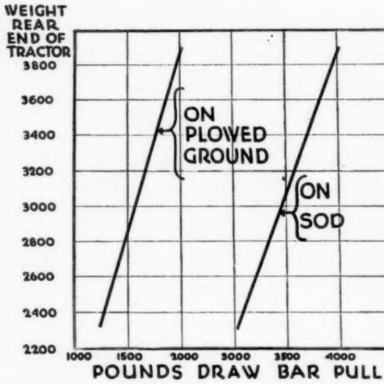
[2]Field engineer, Firestone Tire and Rubber Company. Mem. A.S.A.E.



Two views of Firestone tractor tires mounted on French and Hecht wheels. The wheel at the right is equipped with a weight to secure greater traction. Wheel weights are shown between the two wheels

two to three-plow tractor. The easiest and cheapest way to provide this necessary weight seems to be to fasten it to the wheels. It is preferable to have the weights removable as they are not needed for a major portion of farm work and heavy wheels would be a distinct disadvantage for road work or seedbed preparation.

Steel wheels with lugs consume a large percentage of the total power developed by the engine. Some machines tested, when operating on plowed ground at 3½ mph, required 35 per cent of the total horsepower developed by the engine to propel the tractor. At higher speeds this approaches the total output of the engine and leaves but little for useful work. Because of this it is necessary to operate in second or low gear when doing heavy work with steel equipment. The energy consumed by rubber tires is only one-third to one-half that consumed by steel wheels and lugs. The small amount of power required to propel the rubber-tired tractor results in such a material increase in general efficiency that heavy work formerly done in low or second gear can be handled easily in high when the tractor is equipped with rubber tires. It has been estimated that the application of pneumatic tires to a tractor is equivalent to increasing the horsepower of the engine by 20 to 35 per cent, as far as useful work at the drawbar is concerned. Rubber tires not only increase the power available for useful work at the drawbar, but also effect a very material saving in gasoline. Tests have shown that in some operations this saving is as high as 20 to 25 per cent. The saving of gasoline alone should be more than sufficient to pay for the cost of the rubber tire equipment.



This chart shows the relation between drawbar pull and weight on the tires

When designing these tires it was recognized that they should be made to conform as closely as possible to the sizes which experience has proven to be most desirable for steel wheels. The first tire developed was for the rear wheels of the two to three-plow tractor and approximated very closely in dimensions the 40x12 steel wheels. The rolling radius of this tire is between 20 and 21 in and the section slightly less than 12 in. The tires can be used on a majority of tractors of this size without materially affecting gear ratios, tread widths, or interfering with normal operations. The principle of conforming to the dimensions of the present steel wheel equipment has been followed on other sizes more recently brought out. The following table shows the sizes of pneumatic tires now in production and their principal measurements:

Rear Wheel Pneumatic Tires

Tire size	Type tractor	Size tractor (plows)	Tire section	Overall diameter	Rolling radius
9.00-36	3 wheel	2-3	9.4	55.0	25.60
11.25-24	3-4 wheel	2-3	11.9	46.7	20.95
12.75-28	4 wheel	3-4	13.2	53.0	23.70

The 9.00-36 tire is for the three-wheel or row-crop type machines which require a large overall diameter to provide clearance. The width of this tire makes it practical for use in cultivation of small vegetables with narrow rows, such as peas, beans, potatoes, beets, etc. The 11.25-24 for the two to three-plow, and the 12.75-28 for the three to four-plow machines correspond closely in size to the wheels commonly used on these machines. Both of these tires are narrow enough to operate in plow furrows and the 11.25 can be used in all except the narrowest row crops.

The very low inflation pressure of the tractor tire combined with high traction requires a rim of special construction to prevent slippage of the tire on the rim. In order to meet the requirements for this particular service, a new rim was designed. This rim is of the drop-center type similar, except very much larger, to those now used almost universally on passenger cars. The most important feature of this rim is the sloping base against which the bead of the tire rests. The diameter of the bead of the tire is made 3/16 to ⅛ in smaller than that of the rim on which it fits. When the tire is mounted, the inflation pressure forces the bead of the tire up the sloping base of the rim, compressing the rubber and producing such a tight fit that slippage between tire and rim is prevented. The rims of this type for agricultural tractors have been approved and standardized by the Tire and Rim Association.

The tires used on the front wheels are chosen from standard passenger car sizes and are used on passenger car drop-center rims. These differ from regular passenger car tires principally in the tread design and the lower air pressure carried.

Front Wheel Pneumatic Tires

Tire size	Tractor size, no. of plows	Section	Overall diameter
6.00-16	2-3	6.5	29.4
7.50-18	3-4	7.5	33.8

It is difficult to visualize the ultimate result of the general adoption of pneumatic tires on farm tractors. The greater utility and increased efficiency should open a wide field of new markets heretofore untouched. New machines designed to utilize the advantages provided by rubber tires should stimulate sales in both old and new markets. The savings in fuel and time and the increased value of the pneumatic-equipped tractor to the farmer should be a large factor in helping to put farming back on a profitable basis.

Poison Bran Distributors

TWO poison bran distributors for grasshopper control developed by agricultural engineers of the U.S.D.A. Bureau of Agricultural Engineering, did good work in experimental tests. In early June the engineers cooperating with representatives of the Bureau of Entomology tested the distributors on the 1,600-a farm of C. J. Fenenga, of Hamill, South Dakota. The fields had been plowed, and the poison was applied on the headlands and along the fence rows and roadsides.

An endgate seeder, the hopper of which had been built by the manufacturers in accordance with recommendations of the engineers, spread the bait evenly over a strip about 1½ rods wide. It had no tendency to clog except on steep hillsides.

A lime sower also gave an even distribution over a strip somewhat less than a rod wide. The hopper of this machine was smaller than the one on the seeder and required more frequent filling. It made less noise than the seeder, and had less tendency to clog on hillsides.

Each spreader applied the bait at the desired rate per acre, and with a team traveling 2¼ mph, the seeder covered about 6¾ a per hour and the sower about 3¼ a.

Spreading of bait was begun in the morning when the temperature reached 60 deg. Hoppers started feeding when the sun came out, when there was not too much wind, and when the temperature reached approximately 70 deg. It usually takes 24 hr or longer for the poison to kill. On some heavily infested headlands two or three applications a few days apart were necessary to obtain control of the pest. The regulation mixture of poison bran as recommended by the Bureau of Entomology was used.

Ohio Tests of Rubber Tractor Tires[1]

By G. W. McCuen[2]

I WOULD like to make it clear that I am merely offering data as obtained from a series of tests. In this series it was impossible to consider all makes and types of tractors and tires, to work under all climatic and seasonal conditions, and to duplicate all soil types and all kinds of topography of the United States on a 20-a field in Franklin County, Ohio, in the short space of ten days.

These tests were conducted during the last week of September (1932) and the first three days of October. They were conducted on the Ohio State University farm. The soil was typical of Franklin County, having about a half dozen types in the field, ranging from heavy jack wax to brown silt loam. The field was covered with a heavy growth of timothy and a generous sprinkling of alfalfa plants. The subsoil was extremely dry and the surface wet down about 3 or 4 in as a result of a two-days' drizzly rain on September 26 and 27.

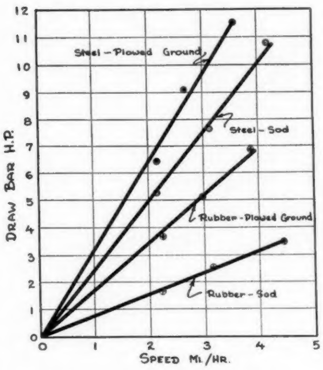


Fig 1. Curves showing rolling resistance of tractor equipped with steel wheels and spade lugs and with low-pressure rubber tires

I mention all of these facts with the hope that these data will not be misconstrued; that they are the result of this one series of tests and were conducted at a time when a farmer ordinarily does his fall plowing. I give you these data for the one series of tests conducted by us under the conditions just described.

The equipment used for making these tests consisted of an Allis-Chalmers "Type U" tractor, the static weight of which, when equipped with rubber tires and wheel weights, was, front, 1700 lb and, rear, 3340 lb—total, 5040 lb.

A Gulley integrating traction dynamometer, a Killefer subsoiler, and 14-in two-bottom tractor plow and numerous other small pieces of equipment necessary to carry on the tests, were used.

The tests were divided into three series to show the effect that low-pressure tires had on (1) rolling resistance of tractor, (2) drawbar fuel economy of tractor, and (3) efficiency of the tractor when plowing.

TEST A. ROLLING RESISTANCE OF TRACTOR

This test was conducted for the purpose of determining the rolling resistance of the tractor when equipped with low-pressure tractor tires or regular steel wheels. The tractor was pulled over timothy sod and over freshly plowed ground at different rates of speed. An interval of 60 sec was used as a standard length of time for the test. The distance travelled during the time interval was automatically recorded on the dynamometer. Two tests were run for each speed. They were run in opposite directions over the field in order to compensate for any difference in grades which was encountered in the course travelled.

It is apparent that the graphs, which were plotted using speed in miles per hour as abscissas and drawbar horsepower as ordinates, are straight-line curves.

If the relationship which appears to exist between the several curves is interpreted when using a constant speed of 2, 3, and 4 mph on sod ground, it is seen that the rolling resistance of the tractor when equipped with low-pressure tractor tires is, on the average, only 31.4 per cent of that with the steel wheel equipment. This difference is due primarily to the fact that the tractor is constantly pushing itself up a slight incline caused by the lugs of the tractor attempting to penetrate the soil.

A study of the data on plowed ground, with the tractor similarly equipped, reveals the fact that the rolling resistance for the rubber equipment is only an average of 54.1 per cent of that with the steel wheel equipment. These were interpreted on a basis of 2, 3, and 3½ mph, as it was impossible to tow the tractor when equipped with steel wheels at a speed but slightly faster than 3½ mph.

TEST B. DRAWBAR AND FUEL ECONOMY

This test was conducted for the purpose of determining the fuel economy and drawbar efficiencies for varying loads on sod and freshly plowed ground. These were determined by (1) measuring or weighing the fuel used during the test and (2) measuring the power required to pull a Killefer subsoiler at different depths and at different speeds.

A course of 750 ft in length was measured off in the field. At each end of the course three surveyor range poles were set at right angles to the course. These served as stations at which to exactly check the dynamometer in or out, note the time required for the test, and turn the fuel on or off.

The entire length of the tests was 1500 ft, going over the 750-ft course in two directions. This was done so as to compensate for any slight differences in grades which might be encountered.

The fuel for the tractor was supplied from the regular tank for deadheading and when making adjustments, and from a small detachable tank during the tests. These tanks were connected to the fuel line to the carburetor by a three-way valve.

When the dynamometer passed the range poles at the beginning of the course, the dynamometer operator signalled, the fuel valve on the carburetor line was switched, and at the same instant the dynamometer and time were checked in. At the end of the 750-ft run, the fuel, dynamometer, and time were checked out. The turn was made and the return trip started. The same procedure then followed as to fuel, dynamometer, and time measurements. At the end of the 1500-ft test the test tank which was

Compilation from Fig 1 Showing Rolling Resistance of Tractor at Different Rates of Travel When Equipped with Steel Wheels and 6-in Spade Lugs, and with 11.25-24 Tractor Tires

Equipment	Ground	Speed Miles per hour	Horsepower To move tractor	Per cent
Steel	Timothy sod	2	5.1	100.00
Rubber	Timothy sod	2	1.6	31.70
Steel	Timothy sod	3	7.7	100.00
Rubber	Timothy sod	3	2.4	31.15
Steel	Timothy sod	4	10.2	100.00
Rubber	Timothy sod	4	3.2	31.70
Steel	Plowed sod	2	6.5	100.00
Rubber	Plowed sod	2	3.5	53.90
Steel	Plowed sod	3	9.8	100.00
Rubber	Plowed sod	3	5.3	54.10
Steel	Plowed sod	3½	11.4	100.00
Rubber	Plowed sod	3½	6.2	54.40

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers held at The Stevens, Chicago, November 1932.

[2]Professor of agricultural engineering, Ohio State University. Mem. A.S.A.E.

Tabulations from Fig 2—Fuel Consumption per Drawbar Horsepower Hour with 12-in Steel Wheels with 6-in Spade Lugs, and with 11.25-24 Low-Pressure Tractor Tires, on Timothy Sod

Drawbar pull	Pounds fuel per drawbar horsepower-hour: Steel, 2nd gear	Rubber, 2nd gear	Rubber, 3rd gear	Per cent fuel consumption: Steel, 2nd gear	Rubber, 2nd gear	Rubber, 3rd gear
1000	1.82	1.63	1.38	100	89.5	75.8
1500	1.30	1.21	1.01	100	93.1	77.7
2000	1.18	1.02	0.84	100	86.4	71.2
2500	1.00	0.94	0.78	100	94.0	78.0

NOTE: Steel wheels in third gear developed a maximum drawbar pull of only 1180 lb, and the results were so erratic that a comparison was not possible.

carried on a small platform attached to the fender was unfastened and weighed.

No tabulation could be made from the curves in Fig 3 showing the relationship between fuel per drawbar horsepower-hour and pounds pull at the drawbar on freshly plowed ground, due to the erratic performance of both steel and rubber equipment.

It is of interest, however, to note in nearly all instances, especially at heavier loads, that the rubber equipment showed a greater efficiency as to fuel economy. The outstanding fact observed in the field was that, for third gear, the steel equipment produced a maximum drawbar pull of only 815 lb with excessive slippage, while the rubber equipment was able to produce 1104 lb pull. The fuel economy at this load was good, considering the loose footing.

Another interesting relationship which is shown graphically (Figs 4 and 5) is the one which exists between the fuel used over a 1500-ft course of travel and the drawbar pull exerted.

These graphs (Figs 4 and 5) seem to give a more favorable comparison as to the relationship between fuel consumed and effective drawbar pull than do the previous curves. It is to be noted that the curves representing rubber tire performance are quite consistent as to type and slope. The steel wheel performance, with the exception of second gear on sod, are not curves which might be classed as typical performance curves.

The curves in Figs 6 and 7 reveal two very interesting facts: (1) In the case of the steel and the rubber equipment in second gear on sod, the tractor travelled at a greater speed with rubber equipment at the same load, until a load of about 1900 lb pull was reached. Then the tractor with steel equipment ran at a greater speed.

Tabulation of Figs 4 and 5

Drawbar pull	Pounds fuel for 1500 ft travel: Steel, 2nd gear	Rubber, 2nd gear	Rubber, 3rd gear	Per cent fuel used: Steel, 2nd gear	Rubber, 2nd gear	Rubber, 3rd gear
Sod Ground						
1000	1.31	1.24	1.02	100	94.3	77.8
1400	1.42	1.35	1.11	100	95.0	78.1
1800	1.57	1.49	1.21	100	94.9	77.0
2200	1.79	1.65	1.33	100	92.1	74.3
2400		1.74	1.40			
Plowed Ground						
700	1.42	1.53	0.98	100	107.7	69.0
800	1.51	1.57	1.15	100	103.9	76.2
900	1.63	1.61	1.26	100	98.8	77.3
1000	1.80	1.64	1.32	100	91.2	73.3
1100	2.03	1.62		100	79.8	

NOTE: The third gear performance of steel wheels was quite erratic when compared to rubber, so the comparison made between steel and rubber are made using second gear as a base.

(2) The reverse is noted on plowed ground. The steel equipment allows a greater speed at low loads until a load of 1000 lb pull is reached; then the rubber equipment makes it possible to maintain a greater speed. The real effectiveness in speed maintenance, when rubber equipment is used, is seen when the tractor is operated at third speed. The effective pull at the drawbar being the same, there is an average increase of 36.7 per cent in speed on

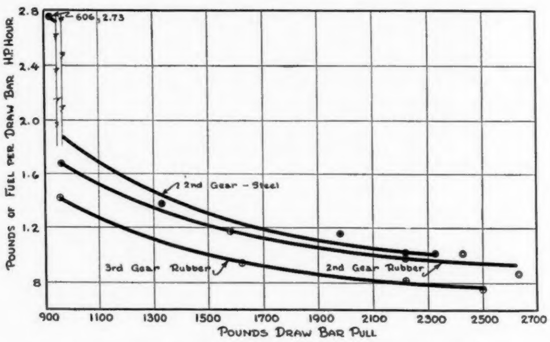


Fig 2. Curves showing drawbar horsepower-hour fuel economy of tractor when operated on timothy sod equipped with steel wheels and spade lugs and with low-pressure rubber tires

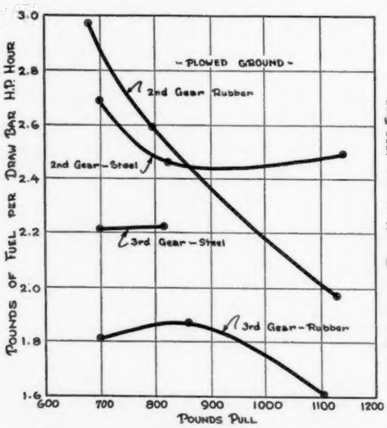


Fig 3. Curves showing relationship between fuel per drawbar horsepower-hour and pounds pull at the drawbar

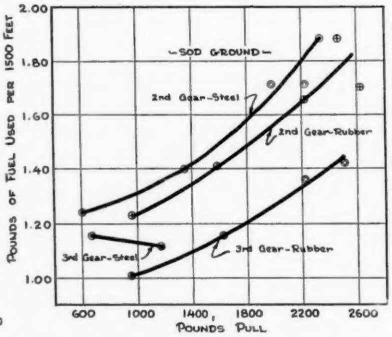


Fig 4. Curves showing the relationship (on sod ground) between fuel used over a 1500-ft course and pounds pull at the drawbar

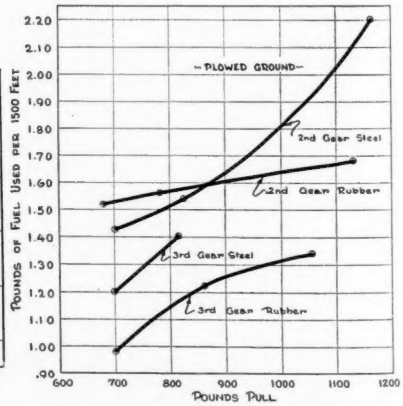


Fig 5. Curves showing the relationship (on plowed ground) between fuel used over a 1500-ft course and pounds pull at the drawbar

Tabulation from Figs 6 and 7 Showing Relationship Between Pounds at Drawbar and Speed in Miles per Hour

Pounds pull	Speed miles per hour: Steel, 2nd gear	Rubber, 2nd gear	Rubber, 3rd gear	Per cent speed: Steel, 2nd gear	Rubber, 2nd gear	Rubber, 3rd gear
Sod Ground						
1000	3.36	3.80	5.18	100	113.0	154.0
1400	3.26	3.56	4.76	100	109.2	146.0
1800	3.14	3.20	4.34	100	113.4	138.2
2200	2.98	2.76	3.86	100	92.6	129.5
2500	2.85		3.30	100		115.7
Plowed Ground						
700	3.42	3.20	4.62	100	93.5	135.0
800	3.36	3.02	4.27	100	89.8	127.0
900	3.16	2.92	4.06	100	92.4	128.4
1000	2.87	2.87	3.92	100	100.0	136.5
1100	2.52	2.84	3.85	100	112.7	152.7

sod ground and 25.9 per cent on plowed ground. The speed factor is an item of vital importance in farming. Since timeliness is the essence of good farming, greater speed increases the possibilities of timeliness.

TEST C. PLOWING

This test was conducted for the purpose of determining the efficiency of the tractor when used for plowing. The ground was in excellent condition for good plowing. The same wheel equipment was used as in all previous tests.

The field was laid out so that nearly uniform land would be had. In order to compensate for differences in soil texture, grades, etc., the tests were conducted in part on each plot, that is, half of the first and second plots was plowed with steel equipment and the remaining half of each plot with rubber equipment. The work was done within a short period of time so as to have conditions comparable. The plots were 700 ft in length.

In order that no fuel be used while deadheading around the ends of the land, or while the dynamometer records were being read, the fuel supply was taken from the auxiliary tank. The fuel in the large tank was used only for plowing. The lapsed time was taken with stop watches.

A uniform depth of plowing was attempted. The depth was measured at intervals of 100 ft, and the average depth determined from these readings.

Ten rounds, five on each land, constituted the test. The ground was moist and in excellent condition for plowing. The tractor was run in second gear when the steel equipment was used, and in third gear when the rubber equipment was used. These gears were selected after preliminary tests were made. A very uniform speed was maintained during each of the tests. The following are the data from this test:

Compilation of Plowing Data

		Steel	Rubber
Area	Length	700	700
	Width	48.937	49.041
	Area, in square feet	34328.7	34255.9
	Acres	0.788	0.786
Depth	Average in inches	6.89	6.82
Time	Minutes	45.083	35.333
	Per cent	100.0	78.38
Acres	Per hour	1.048	1.333
	Per cent	100.0	127.2
Fuel	Pounds used	12.81	9.72
	Pounds per hour	17.04	16.50
	Pounds per acre	16.26	12.37
	Per cent	100.0	76.13
Speed	Miles per hour	3.53	4.50
	Per cent	100.0	127.1

The simplest interpretation which can be made from the foregoing plowing data and which would be of interest to farmers is the fact that, when the tractor was equipped with low-pressure tractor tires, it was able to plow 27.2 per cent more ground per hour and use 23.83 per cent less fuel per acre. In addition to these major savings of time (whch means a saving of labor) and fuel, it was observed that a better granulation of the soil resulted when the tractor was operated in third gear. This higher speed was obtained on rubber tires only. This better soil granulation would, under ordinary farm practices, mean a saving of at least one disking of the field before planting.

SUMMARY

The following is a brief summary of the results of this one series of tests, to ascertain the relative efficiencies of the same tractor when equipped with regular wheel equipment and low-pressure tire equipment. The steel wheels were the standard 42 by 11⅛-in wheels with 6-in spade lugs on the rear and 28 by 4 plain band type in front. The rubber equipment consisted of Firestone 11.25-24 pneumatic tires on the rear and 6.50-16 on the front. The rear tires were inflated to 12 lb and the front tires to 16 lb. pressure.

1. At normal working loads the rubber tractor tires in second gear required an average of only 91 per cent and in third gear only 75.5 per cent as much gasoline per drawbar horsepower as the steel wheels in second gear.

2. The greater efficiency of the rubber tires makes it practical to do work in third gear which could be done only in second or first gear with steel wheel equipment.

3. Under all conditions tested the rubber tractor tires developed a greater effective drawbar pull than the steel wheels with lugs.

4. The low-pressure tractor tires gave a higher average speed than steel wheels. For the same effective drawbar

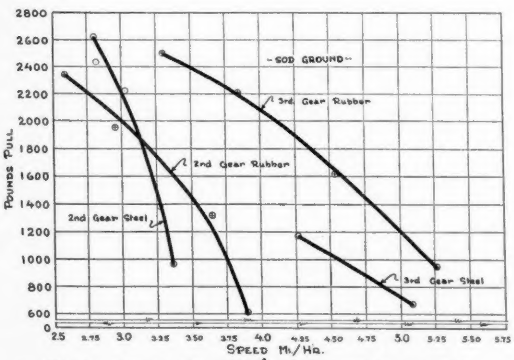


Fig 6. Curves showing the relationship (on sod ground) between pounds pull at the drawbar and speed in miles per hour

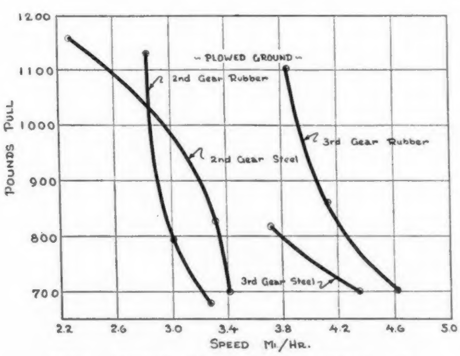


Fig 7. Curves showing relationship (on plowed ground) between pounds pull at the drawbar and speed in miles per hour

pull the average increase in speed on sod in one series of tests was 36.7 per cent and on plowed ground 25.9 per cent. This higher speed would, of course, result in a corresponding saving in time.

5. The rolling resistance of the tractor when equipped with low-pressure tractor tires on sod is 31.4 per cent and 54.1 per cent of that of steel wheels. This low rolling resistance is a large influencing factor in a greater efficiency of the tractor. The power of the engine is not consumed to so large a degree in the propelling of the unit, but is delivered to the drawbar as useful work.

6. A greater efficiency of the tractor was obtained when pneumatic tractor tires were used as wheel equipment for plowing. This increased efficiency was a result of lowering the fuel consumed per acre plowed 23.83 per cent and increasing the area plowed by 27.2 per cent in the same unit of time.

7. While not measured in these tests, it was obvious that the tractor, when equipped with pneumatic tires, was a more comfortable machine for the tractor operator to ride. The elimination of severe shocks and impacts should give the tractor a much longer life.

8. The equipping of the tractor with low-pressure tractor tires makes it possible to use the tractor for a greater variety of work without making any changes in wheel equipment.

Farm Engineering Management

By George W. Kable[1]

A PUBLIC utility man asked me recently what proportion of the profit and satisfaction from the use of electrical equipment on farms was due to the equipment itself, and what proportion to the educational effort in helping the farmers to make proper selection and use of the equipment. The question emphasizes once again a fact with which I have become more and more impressed in recent years. This fact is that engineering and management on the farm cannot be separated, and that engineers and farm management men are making a mistake when they attempt to draw sharp lines between the engineering and management phases of farming in order to perpetuate an outgrown college division of subject matter.

The electric kitchen helper on an inconvenient shelf in a cupboard is a frozen asset and not a convenience. Permanently located in an accessible position near the center of food preparation, it is not only a labor saver but a real joy. To create that joy and yield a return on the investment, the kitchen helper must be selected not only for its mechanical perfection and price, but it must fit the job to be done and the place in which it is to be used. The location of a little shelf near the kitchen cabinet may be equally as important as the purchase of the mixing device itself.

The kitchen helper is mentioned because I have had just that experience with it, and it is typical of many of the problems of equipment and management, both in the farm home and in the farm business. A tractor purchased for mechanical perfection, without regard to the operations it will perform, or the size and shape of fields where it is to be used, is likely to be a bad economic venture. Many of them have been. The small, odd-shaped field should not prohibit the use of the tractor if other conditions favor it; but when the good, "engineered" farm tractor comes through the gate, it should bring with it an equally good and carefully developed management plan for the use of that tractor.

In colleges where there have been strong agricultural engineering and strong farm management departments, there have frequently been arguments over the "ownership" of certain academic subjects. The very fact that two hens want to set on the same eggs causes one to question whether it would not be better to have one nest and use less time rolling eggs. Some of the best engineers I know are farm management men, and some of the most practical farm management men are connected with agricultural-engineering departments. We are all familiar with the excellent farm machinery and development study program conducted by the agricultural economics department of one of the western agricultural experiment stations. We have recently read in AGRICULTURAL ENGINEERING of a farm engineering management study being conducted by an agricultural-engineering department.

[1]Director, National Rural Electric Project, College Park, Md. Mem. A.S.A.E.

Agricultural engineering and farm management departments have a number of things in common. The teachings of each apply to all the other agricultural departments. Each has for its end-point more economical production, less drudgery, and a bettery utilization of labor. Each has problems which should receive simultaneous consideration. Should a machine be designed or selected, and the farm management man then work out a method for using it; or should the problem of production be first considered, and the machine purchased or designed to fit the farm management plan? The hackneyed answer of letting the management man tell what is needed and the engineer produce it is not what is happening in practice.

Twenty years ago our economic engineering problems on the farm were fewer and of less importance. In our early studies of farm management we were largely interested in yields per acre. During the rapid technological transition period of the past two decades, our focal point of interest has changed to "dollars per man." Just now, with our prices of farm products all but being wiped out by world economic conditions and with many people seriously questioning our monetary and social systems, our measure of value for tomorrow may be "smiles per day."

Whatever comes, it appears that the engineer and the farm management man must work very close together, if not in the same harness—if we are to effectively meet the problems of the day and not merely perpetuate a system. With so much of economic success of today dependent upon power and machinery and its intelligent use, it would seem that a joint course in farm engineering management might offer promise. Admitting the fact which we all know, namely, that the problems we are meeting in agriculture today are not the ones we solved in the classroom yesterday, and that our ability to solve problems is not based upon what we know about a mowing machine, a textbook ventilation system, or yesterday's statistics on man-hours, but rather upon a knowledge of fundamentals, it is likely that some subjects might well be omitted in such a course, in order to learn more of the fundamentals of engineering and of the agricultural problem as a whole. It is possible that some institution not hampered too much by precedent or prejudice might make a real forward step by establishing a department of agricultural engineering management and seasoning it well with a study of social relationships.

EDITOR'S NOTE: Every agricultural engineer will endorse what Mr. Kable says about the need of a closer engineering-management tie-up. Closely related to it is another thought to which our group may well give serious consideration. In the general industrial and business field, engineers are more and more getting into management or administrative work. For those whose natural bent is for this type of work, this is a field to which they might well aspire. In many respects the training which the engineer receives especially qualifies him to undertake administrative positions, and particularly for the management of farming enterprises.

Problems in the Design of Low-Pressure Tires for Farm Tractors[1]

By E. F. Brunner[2]

THE application of pneumatic tires to various types of farm tractors is not new, but during the past six months a practical low pressure tire for agricultural tractors has been worked out. This new tire has aroused an ever-increasing amount of interest on the part of farmers, implement dealers, and manufacturers.

About nine years ago industrial plants started equipping tractors for factory and yard work with 42x9 and 44x10 pneumatic tires. Later on tractors used for and with other road-building machinery were so equipped. The tires used in both types of service were regular high-pressure truck tires made of many plies and to operate at from 50 to 90 lb of air pressure.

During this period high-pressure truck tires in the same sizes were tried out on agricultural tractors in general farm and orchard work. Due to the high cost of new tires and the fact that they did not have the proper design of non-skid and were operated at too high air pressures, they were not generally accepted as satisfactory by the industry.

However, the use of worn-out high-pressure truck tires which were obtainable at relatively low cost have proven fairly satisfactory for certain types of general farming. These worn-out tires still had to be operated at around 25 lb air pressure to prevent the tires from creeping on the rim. and with practically no non-skid the tires would not given the maximum or necessary drawbar pull to make them universally practical for general farm work.

All airplanes were equipped with high-pressure tires until about four years ago. They invariably became stalled in the mud during the rainy season. At times it was impossible to operate at all. We realized that with an extremely low pressure tire airplanes could operate regardless of field conditions. Also that most emergency landings could be safely made. At that time the new "airwheel" airplane tire to operate at from 5 to 12-lb pressure was put on the market. The success of this tire can be readily appreciated by its present general acceptance by the industry.

These low-pressure airplane tires have also been marketed for use on tractors in the South and Southwest for general orchard work and for certain types of farming over the past two years. The sizes used on tractors are 26x11-6 front and 46x20-10 rear. The air pressure used is 5 lb rear and 15 lb front. Due to the extremely small wheel diameter and low air pressure, the tire would creep on the wheel. To prevent this the rim and tire bead have on each side a series of lateral keyways or notches. Tractor installations made two years ago are giving satisfactory service, and the tires are still in excellent condition.

This brings us up to the most recent development in low-pressure pneumatic tires for farm tractors. Speaking from the standpoint of our experience, we believe the following points must be considered when designing a farm tractor tire:

1. The tire must be such that it will operate satisfactorily at low air pressures
2. The tread design must be designed to give maximum resistance against ground slippage
3. The tire must be securely held to the rim to prevent creepage
4. The tire must be easy to apply and remove from the rim
5. The rubber industry must set a standard for tire sizes and rim contours
6. The cost of the tire rim and wheel must be relatively low
7. Principal advantages to be obtained from low-pressure tires on farm tractors.

A detailed discussion of the foregoing points we believe will bring out the most important phases of the development of low pressure tires for tractors.

Low Air Pressure. As has already been pointed out, the airplane low-pressure tire has operated at as low as 5 lb pressure for the past four years. The experience gained has been quite a factor in making what we believe is a satisfactory farm tractor tire.

The carcass must be flexible enough to withstand the extreme deflection or radial movement of the tire. The deflection for best operating conditions is, we believe, 20 per cent for the farm tractor tire compared to 11 per cent for the high-pressure truck tire, and 14 per cent for the bus balloon tire. To use a still greater deflection as a regular thing would reduce the life of the tire by separation and (or) fabric breaks. To use a lower deflection, that is, more air pressure, would handicap tire performance by reducing drawbar pull, resulting in excessive ground slippage. Maximum deflection results in maximum ground contact area which you can readily appreciate keeps the unit ground pressure at a minimum.

The best air pressure for all-around performance is about 12 lb in the rear. This pressure at 2000 lb load for the 11.25-24 tire corresponds to a deflection of 20 per cent. If the load is less than 2000 lb per tire, the air pressure can be proportionally reduced.

Present indications are that six plies will be sufficient for rear tires and four plies for front tires.

Tread Design. The non-skid design should be such as to give the maximum tractive effort with least tearing up of the ground or digging in should slippage occur. Our typical "diamond" design has been used, but the proportions between button width, groove width, and non-skid depth are entirely different than for tires running on hard-surfaced roads. The grooves between the buttons have been made extremely wide to reduce share action in soft ground to a minimum. The diamond while still 60 deg is much larger than generally used in similar sizes of truck and bus tires. The

A tractor equipped with low-pressure rubber tires especially designed for agricultural requirements

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers held at The Stevens, Chicago, November 1932.

[2]Tire design division, Goodyear Tire and Rubber Co.

center portion of the diamond has been removed to provide additional ground shear action. Due to the large deflection and the angularity of the non-skid design, the tread is entirely self-cleaning. This is important as it will keep the spinning of the wheels in soft mud down to a minimum. A broken-up design also gives the tire greater flexibility resulting in less slippage.

Fit of Tire on Rim. The rim adopted for the farm tractor tire is of the drop-center type with a 5-deg tapered bead seat. Our tire has the bead seat molded ⅛-in smaller in diameter than the rim, thereby giving 1/16 in compression or squeeze between the tire and rim on each side. Before any Goodyear tires were put on the market, extensive tests were made in the laboratory to make sure that, with our reinforced bead construction and 1/16 in compression, there would be no creeping of the tire on the rim at 50 per cent over maximum drawbar pull.

Easy Tire Application. The drop-center type of rim which has been adopted for farm tractor tires, is also the universal standard type for passenger cars. Therefore, practically everyone is familiar with the necessary routine of mounting and dismounting of tires on such rims. The original rims supplied with the first farm tractor tires had rather shallow wells. Recently the well depth was increased to make tire mounting still easier.

Standard Rims and Tires. Recently the rubber industry set up standards for both farm tractor rims and tires. Therefore, all future rims regardless of who makes them are to be made to the same dimensions so that all makes of tires will be interchangeable. Tire sizes and cross sections have also been agreed upon by the rubber industry. The cross section of the rear tires is to be the same as the corresponding size of bus balloon tire. For front tires, the new low-pressure tire cross sections have been agreed upon. As a matter of information the tires and rims below are being recommended tentatively for the various types of farm tractors:

		FRONT		REAR	
		Tire	Rim	Tire	Rim
Small row-crop tractors (3-wheel)		8.50-10	8.50-10	9.00-36	6.00-36
Std. row-crop tractors (3-wheel)	Std.	6.00-16	4.50-16	11.25-24	8.00-24
	Option.	6.00-16	4.50-16	9.00-36	6.00-36
Std. 4-wheel tractors	Std.	6.00-16	4.50-16	11.25-24	8.00-24
	Option.	6.50-16	4.50-16	13.50-24	8.00-24
Large 4-wheel tractors	Std.	7.50-16	4.50-16	13.50-24	8.00-24
	Option.	7.50-18	4.18-18	12.75-28	8.00-28

In addition to the above, there may be one or two additional tire and rim sizes. However, from a cost standpoint, it is advisable to have as few sizes as practical to cover the range of tractors.

Low Cost. You can readily see that to make pneumatic tires practical for farm tractors the price must be considerably less than truck, bus, and airplane tires. For example, if a $1000.00 tractor were to be changed over to 42-9 high-pressure truck tires and tubes, the two rear tires and tubes would cost the farmer about $350.00. In addition, the wheels and rims would cost an extra $75.00, making a total of $425.00 for rear pneumatics only. If the front were also changed, the pneumatic equipment would be about 55 per cent of the original cost of the tractor. This high price also holds for the 46x20-10 "airwheel" installation, which ran approximately $400.00 for a complete change over.

Now compared to the above high costs the new farm tractor tires and wheels in sizes 11.25-24 rear and 6.00-16 front will cost the farmers about $200.00 installed. The cost of a tractor designed to take pneumatic tires will be but very little greater than existing steel-wheel-equipped tractors. This will of course have to come in future designs where strength, weight and engine size can be reduced to compensate for the cost of the pneumatic equipment. This same process came about in the truck field when pneumatic tires were adopted in place of the solid tires.

Low Pressure Tire vs Steel Wheels. No doubt the advantages to be gained by the use of low pressure tires on farm tractors will be covered in detail in other papers. However, I will enumerate the major advantages, simply as a matter of information:

1. The tractor can perform farm operations at higher speeds
2. It is permitted to run over improved roads where steel wheels are prohibited
3. Materially lower fuel and oil consumption
4. More power available for useful work due to lower rolling resistance
5. Easier on the operator
6. Makes tractor available for a greater variety of farm work
7. Can be operated on barn floors, in yards, on lawns, etc.
8. Seedbed packing is reduced to a minimum due to low intensity of ground pressure, which can be reduced to a minimum of 7 lb for this type of work
9. Increased drawbar pull at higher speeds.

Soil Erosion in the Palouse Country[1]

By P. C. McGrew[2]

THE slopes in the Palouse region in eastern Washington are quite steep; in fact it would be difficult to find a single half section which did not have cultivated slopes in excess of 40 per cent, the average of some on the best farms being 20 to 30 per cent.

It is readily seen that broad base terraces are not adapted to such slopes. Narrow terraces can be built on them, but it would be difficult to conduct farming operations with present types of power equipment. The terraces on steep slopes have not been built long enough to determine their effectiveness in controlling erosion.

During the first twenty years after the sod was broken the land was mostly cropped to spring wheat, and spring plowing was practiced to a considerable extent. The season of most severe erosion is during the winter, and with the stubble standing in the field practically no erosion occurred. Also during the early years the top soil had a high humus content and was filled with many small roots which did not entirely disappear for many years. These roots and the mellow condition of the soil promoted moisture penetration so that the erosion during the early years was not great even when the soil was in a cultivated condition during the season of erosion. As the humus content of the soil decreased there was a tendency for the soil to run together and for moisture penetration to be slow. Winter wheat gradually replaced the spring wheat and the use of summer fallow became more general.

The spring preparation of seedbed and growing of spring crops would be successful in combating erosion. This, however, would not fit in with the present system of farming as the period in the spring when field work can be done is very short, and the acreage which could be handled per man would be very much less than when the crop is planted in the fall.

The outstanding need for erosion control is the development of a control method which does not interfere with the present system of farming the land, or else the changing of farm practice to have the land covered with vegetation during the season of most severe erosion. The latter method does not seem possible in the drier belt, but as the slopes are generally less steep in the dry area the use of terraces may be a solution. The most important areas, however, are those of favorable rainfall, and the slopes are very steep over much of this area.

[1]A contribution to the work of the A.S.A.E. Committee on Soil Erosion Control, 1931-32.

[2]Agricultural engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Mem. A.S.A.E.

A Study of Temperatures in Dairy Stables[1]

By M. A. R. Kelley[2]

THE PURPOSE of the tests described in this paper was to study the effect of different stages of stable temperatures and of sudden changes in temperature, and the consequent necessity of insulating dairy barns as a factor in temperature maintenance and maximum milk production. What is the best stable temperature for winter milk production, and what degree of temperature control should be provided in barn construction? The answers to these questions are to be found in the individual records of 96 cows for the past two winters. In addition to these data obtained under controlled conditions, the records for a brief period from 100 farmers' barns were studied.

These studies were made at the Brook Hill Farm[3], at Genesee Depot, Wisconsin, in cooperation with the University of Wisconsin[4] and the U. S. Department of Agriculture[5].

AN OUTLINE OF THE EXPERIMENT

The barn was one and one-half stories, 36 by 190 ft long, and normally housed 100 cows. The stable was divided into four equal sections by building partitions across the the barn, so as to stable 22 cows in each section. Eight additional cows were kept in another barn with open doors and windows, the stable temperature being allowed to fluctuate with the weather.

Herd management and practices were conducted so as to meet the requirements for certified milk. The size of the milking herd is ordinarily 600 cows or more, and the selection of our test cows was made after a study of the herd records. Sixteen high-grade Guernseys and six Holsteins were placed in each section of the test barn. These selections were made on the basis of age, weight, period of lactation and milk yield. A very even balance of these factors was obtained in all sections. The production of each cow was checked by a preliminary run of ten days prior to the test.

Five different stable temperatures were studied concurrently. Three stages were maintained steadily for periods of 10 to 20 days with a variation of but 1 to 2 deg, the stages ranging from 45 to 65 deg. The temperature of the two other stables was permitted to fluctuate with the weather.

The analysis of the data has not as yet been completed and detailed reports will not be available for some time. Records were kept with respect (1) to the weather, including temperature, humidity, wind velocity, barometric pressure and prevalence of clouds; (2) to the stable, including air, wall, and floor temperatures, humidity, ventilation, and illumination of interior and exterior; (3) to the cows, including feed, water consumption, age, weight, individual milkings and butterfat records for each of the 96 cows, also respiration, pulse, and rectal temperatures for 8 cows in each section. Last winter all these records were made at regular periods for 88 consecutive days, while during the previous winter similar records were obtained for January and February.

A study of this kind is difficult for several reasons. First, cows are living beings and react to many things beside feed and the more apparent factors of environment, so that reliable results cannot be secured by a few uncorrelated trials. Second, the comfort of the animal is affected by radiant heat from walls, windows, and ceilings; floor temperatures; and drafts which are difficult to evaluate as well as by easily measured factors such as air temperature and humidity.

It is impossible to study the effects of stable temperature, or environmental conditions upon the milk production and health of the animal, without an understanding of the physical air conditions or the physiological aspects of heat generation.

ESSENTIALS OF HEAT CONTROL

Food is the sole source of energy used by the cow in warming the stable. The dairyman tries to induce his cows to eat as much feed as can be economically converted into milk; hence, it is desirable that the temperature should be low in order to maintain the appetite and general vigor of the cow and yet not so low as to cause wasteful oxidation for keeping herself warm. Cows housed in cold barns utilize food energy in maintaining body temperature, or even consume body tissue, which might be used in milk production if the stable were more comfortable.

Many factors affect the amount of heat produced by the dairy cow; feed, weight, age, and milk production are the more important factors. In this discussion we will assume normal and average heat production of about 3,000 Btu per hour and study the manner of animal heat loss as it may be related to her comfort. The heat which the animal body is continually generating must be dissipated at such a rate that the temperature of the body will be maintained. The body is able to regulate its temperature very closely within certain limits by varying the rate at which moisture is evaporated. Armsby and Kriss found that with a chamber temperature of 57.5 deg F a full-coated steer lost 74.3 per cent of its heat production by radiation and conduction and 25.7 per cent as latent heat of water vapor, while at 70.7 deg it lost 55.8 per cent by water vapor.

Recent tests on a dairy cow also reveal that the proportion of total heat loss by latent heat of water vapor (40 per cent) is not greatly changed at relative humidities ranging from 55 to 87 per cent when the chamber is held at 71 deg. It will be noted that the percentage lost in this manner is similar to that of the steer. Another test is available showing that the rate of insensible heat loss through the skin and lungs is affected by environmental temperature. It was found that change of live weight due to the insensible loss from skin and lungs by a steer on a maintainance ration was 8.4 kg at 12 deg C (53.6 deg F) and 16.1 kg at 27 deg C (80.6 deg F), and under a slightly different plane of nutrition was approximately 4.0 kg at 5 deg C (41 deg F).

We do not know how important these data are quantitatively with respect to their application to a cow in milk, but they do indicate the general tendency for high insensible losses to accompany high temperatures. There are, however, sufficient exceptions to this relation to make it difficult to draw more than a general conclusion. It is also evident that a sudden change from cold to warm temperature may not have quite the same effect as when these factors are reversed. Our tests reveal similar discrepancies which make it difficult to interpret the results.

Heat, aside from evaporation of moisture from the skin and lungs, may be given off directly to the surrounding air by convection and conduction or lost by radiation.

Heat is transferred by conduction when it is conveyed from one molecule to another. Air in contact with a

[1]Paper presented at a meeting of the Structures Division of the American Society of Agricultural Engineers held at The Stevens, Chicago, November 1932

[2]Agricultural Engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Mem. A.S.A.E.

[3]Howard T. Greene, owner. Dr. Sobey Okuyama, veterinarian and bacteriologist, was responsible for herd management and health of stock, and Dr. Henry Otterson, chemist, made the butterfat tests

[4]I. W. Rupel, department of animal husbandry, and E. R. Jones, department of agricultural engineering

[5]R. R. Graves, Bureau of Dairy Industry

warm body is warmed by conduction. Convection currents are set up by the internal heat of the body conducted to the skin surface and given off. The air expanded by heat and diluted by the water of evaporation from lungs and skin is made lighter and is forced upward by the cooler air from below.

Heat transferred by radiation travels in straight lines and at approximately the same rate as light (186,000 mps), without appreciably heating the air, until it strikes surrounding bodies or surfaces, where it is absorbed, transmitted, or reflected. At constant temperature bodies radiate as much energy as they receive. Thus if the walls are at the temperature of the body, there is no loss by radiation from the body.

The rate of evaporation is limited by the relative humidity of the air, and at saturation there is no loss of body heat by evaporation. Convected heat travels only at the rate, and in the same direction, as the air that conveys it. Hence, the loss of heat by convection is proportional to the rate of air circulation.

The sense of the feeling of cold may be avoided by raising the surrounding air temperature, or by decreasing the radiation loss from the surface. It has been found more efficient to warm the surrounding walls or decrease the radiation, than to produce the same effect by raising the air temperature.

In a stable crowded with cows the loss of radiant heat to the cows in adjacent stalls is small owing to the warm surroundings. However, it is readily seen that, if the wall temperatures are very cold such as might be the case if the dairy cow is surrounded with a large amount of glass surface and thin walls exposed to cold outside temperature, it would then be necessary to have a higher air temperature in the stable in order to counterbalance the excess heat by direct radiation. If, on the other hand, the body is surrounded by warm inside walls, a lower air temperature would be comfortable. Herein lies a clue to the effect of different stable temperatures upon the cow when wall temperatures are warm during periods of warm weather, and when they are cold during more severe exposures. Years of experience in this test barn reveals that not all cows are able to stand being placed in an end stall as the extra exposure due to the proximity of the outside wall is too severe a tax on their heat-regulating mechanism. The cold wall on one side and the warm body of the adjacent cow on the other side certainly produces unequal radiation losses from the sides of the cow.

POSSIBLE EFFECT OF ARTIFICIAL HEAT

Use of artificial heat may also unbalance the heat-regulating mechanism of the cow. In this test electric heaters were used in a few instances to help maintain constant temperatures, but tended to reduce milk yields, probably due to the disturbing effect of the radiant heat.

Another measurement of efficiency of resuts of various stable temperatures, but which is more or less intangible as measured at the milk pail, is that of the general health and vigor of the animal. These results are visible to the eye but not always on the milk scale. All will agree that maintenance of health is of prime importance. Brightness of eye, alertness, slickness of hair and skin are accepted as marks of vigor and health. A dull, listless expression may be considered as a danger signal suggesting that the health is being impaired. These indicators help to reveal the composite results of several intangible factors.

An examination of the respiration, pulse, and rectal temperature aids greatly in the determination of the state of health of the animal. It then appears that the departure of such factors from the normal may serve as a measure of the effects of the environments upon the efficiency of the cows in milk production. However, a search through textbooks reveals a meager amount of data with respect to normalcy of these units when applied to the dairy cow. The summarization of these data obtained in our tests should add materially to our knowledge of this subject, as they were measured concurrently with a number of other factors.

ANIMAL COMFORT

Dairymen assert that dairy cows must be comfortable in order to produce heavily and efficiently. The results of our tests fully affirm this statement. A cow cannot be comfortable when shivering with cold, and she will not produce the maximum amount of milk. She must have a comfortable stall, a good bed which can easily be kept clean, freedom from annoyance, clean air, and sunlight. She cannot be comfortable or healthy in a muggy, ill-ventilated stable. It is more important to keep cows in good health than to effect a cure after the damage is done. If she is subjected to adverse environmental conditions, the additional strains added to that of milk production decrease her efficiency and lowers her resistance to disease. Air temperature is not a complete index of the comfort of the animal.

The comfort of the body is principally dependent upon the rate and manner of heat loss from the body. The three conditions of the air which affect the removal of body heat are temperature, relative humidity, and air movement. Although stated in the order of their general importance, it is more convenient to discuss them in the reverse order, since we can discuss but briefly the last two factors.

In the studies leading to the determination of the zone of comfort for man, the investigators were greatly aided by the fact that subjects were able to state their feelings. In the study of dumb animals one is denied this aid. We may study the milk and butterfat yields and compare them with the factors under consideration, but milk and butterfat yields are the composite result of several factors which can not be isolated. Hence it is desirable to record all factors which are sensitive to environmental temperatures.

We have known for several years that uniformity of temperatures is highly desirable in the storage of fruits and vegetables. It is now revealed that it is of similar value in producing the best results at the milk pail. Uniformity or evenness of stable temperature is more desirable than the temperature stage, when kept within the limits outlined later.

In these tests ventilation was regulated so as to aid in maintaining the desired temperatures and at the same time avoid bad stable air conditions. Heat was available to raise stable temperatures when necessary. On several occasions excessive drafts resulted when an attempt was made to hold stable temperatures lower than outside conditions warranted. As the results of these excessive drafts several cases of pneumonia developed. The same results were obtained both winters.

Warm balmy days of the January and February thaws are the dangerous days for stock housed in warm barns. Temperatures of 30 to 40 deg accompanied by drafts appear favorable to chills, as the attendant is likely to neglect doors and window openings at this time or open them too freely. The results are harmful drafts followed by sickness and excessive losses in milk yield. Dr. E. Vernon Hill of Chicago, defines drafts "as a current of air coming in contact with the human body which by reason of its velocity, its temperature, its humidity or any combination of these, abstracts more heat than the body surface normally dissipates." We may now extend this to dairy cows and emphasize the need for avoiding harmful drafts.

Relative humidity is a factor in the determination of the comfort of the animal, but, under the ordinary range for stable conditions, it is of far greater importance to the life of the structure. The walls of the building, when cold, act as a condensing surface for collection of moisture. The higher the humidity, the more readily this deposition takes place, and the sooner the decay of the ceilings, wall boards, etc. If adequate ventilation is

maintained, the effect of relative humidity upon the cows is not apparent generally under winter stable conditions, and it is not until the temperatures exceed 75 deg and are combined with the high humidities that their results become apparent. The upper limits of 80 per cent humidity is herein prescribed and can be easily obtained with adequate ventilation, while the relative humidity of the stable will rarely go below 40 per cent and seldom below 50 per cent. During our tests a stage of approximately 70 per cent was obtained with a small variation above and below. Thus in this prescription we assume a practical limitation, rather than the specific effect on comfort, which must be left to future discussion. Although we have seen that at a temperature of 71 deg the effect of relative humidity variation of from 55 to 90 per cent is not particularly strong, it is none the less active and becomes more apparent when the wet-bulb temperature and total heat of the air are considered.

OPTIMUM STABLE TEMPERATURES

Stable temperature ranging from 40 to 65 deg in stages of 5 deg were studied in our test barn; temperatures in the second barn were permitted to vary with the weather, and these results checked against the records of 90 farm barns with a personal check on fifty of these. Sufficient data have now been obtained to prescribe a zone of comfort for the dairy cow and to discuss its practical limitations and applications.

Dr. Forbes says that "the critical temperature of the environments for an animal is the lowest temperature at which there is the minimum heat production."

The point at which physical regulation of body temperature gives way to chemical regulation is not fixed and unvarying but is affected by the food eaten. When the stable temperature falls below the critical temperature, there must be an addition of more food or body tissue in order to maintain the body temperature. It is evident that the critical temperature for cows on heavy feed for maximum milk production would be lower than for cows on maintenance ration or when fasting, since food consumption stimulates heat production and lowers the temperature at which the animal draws upon her tissues in order to keep warm.

Critical temperature must not be confused with optimum stable temperature as they are not coincident except under certain conditions. The best information available places the critical temperature of a dry cow on maintenance at approximately 50 deg or slightly more. For high-producing cows consuming large quantities of feed this point must be lower, and may be 40 deg or less.

Recent tests place the upper temperature limit around 80 deg, at which point there appears to be a decline in milk yields and a change in composition of the milk. In defining optimum stable conditions we must not only consider the physical reaction of the cow, and maximum efficiency of milk production, but also the practical limitations and conservation of the structure. Hence optimum stable conditions are those which supply clean air at a desirable temperature for breathing, without harmful drafts, and maintain such a degree of comfort as to obtain normal regulation of body heat loss and maximum energy yield at the milk pail.

In addition we must recognize that the heat-regulating mechanism of the body is at a different tonus in summer and winter. One feels comfortable at a room temperature of 70 deg during the winter, but feels distinctly cool or chilly in a theater at that same temperature when he enters from a warm street temperature of 90 deg on a summer day. A cow will feel a different degree of comfort at identical stable air temperatures with cold walls—due to low outside temperatures or rapid loss of heat—than with one having warm walls. Thus our climatic zones suggest the practical limitations as shown in the accompanying diagram. Our best temperatures lie between the limits of 50 and 55 deg. Small variations from this stage are of little importance, but departure from this zone produces apparent differences, and wide fluctuations even about this zone produce a more rapid decline in lactation, than when held at a uniform level. It was learned that cows do better when kept comfortably cool.

COMPARISONS AT DIFFERENT TEMPERATURES

Comparing the cows in sections held at 50 to 55 deg it was noted that they were more alert, eyes brighter, hair more glossy, appetite good, while those in sections having temperatures from 60 and 65 deg stood with ears back, were more restless, had harsh hair, were harder to clean, and had less appetite. At the higher temperature odors were more noticeable and health inspectors objected to these. The milkers all preferred the cooler temperatures (50 to 55 deg).

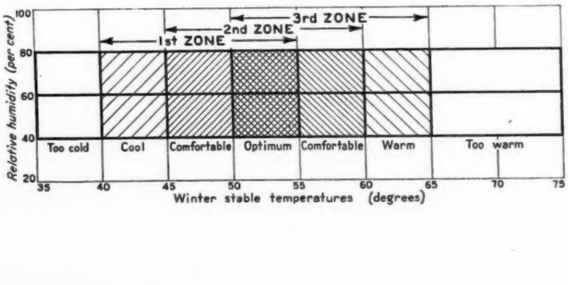
Examination of data from various sources appears to indicate a loss of milk when temperatures drop below 32 deg and remain low for any length of time. When they descend below 20 deg, the decrease is augmented and bears a relation to the degree of protection afforded by the structure. Experience shows that it is at this stage conservation of animal heat is necessary in order to obtain desirable stable temperatures. Losses in milk yield in "climatic barns" are 15 to 25 per cent or even more, while in barns with temperature control these losses were decreased in some cases below 2 per cent under like weather conditions. The rate of animal heat loss as measured by a kata-thermometer, in a stable varying with the weather, was three times that of the loss in a controlled stable on the same date.

The stage of temperature at 50 to 55 deg is most desirable from many angles. Temperatures slightly above or below these will be satisfactory if held without too wide fluctuation. Hence in the first zone a lower stage is desirable than in the second and third zones, because they will more closely conform to the average climatic conditions and can be maintained more readily. Acclimatization is a factor, as cows held at 60 deg in the third zone may be just as efficient as cows held at 50 deg in the first zone. The best efficiency results when well-fed cows are kept comfortably cool, and we have seen from previous discussions that this is determined by many factors.

In our test barn we found it impossible to maintain a temperature as low as 45 deg when it was above 30 deg outside, even with drafty ventilation and with the circulation of as much as possible of the outside cooler air. Again it was difficult to hold the stable temperature down to 50 deg with an outside temperature of 42 deg; a temperature of 60 deg could be held with 40 deg outside, but it was difficult to hold 65 deg when 30 deg or below outside, and additional heat in this stable was often required at this point.

As test data relating to this feature are not yet available, these examples are the result of common observations and illustrate the necessity of stating desirable stable temperatures in terms of the climatic zones, in order to keep them within the practical as well as the most efficient limits.

The general conclusions made with respect to stable temperatures as revealed in these tests and as discussed above with regard to the limitations are summarized graphically in the following diagram.



Terraces to Conserve Surface Runoff[1]

By R. E. Dickson[2]

HISTORY is replete with stories of drought, famine, and disaster. Intermingled with these are accounts of water conservation and irrigation. Texas agricultural experiment station workers, in checking the agricultural practices in vogue throughout the western portion of the state, found that the proverbial old water barrel to be full of leaks. The required 6 in of water that must pass through the growing cotton or sorghum plant in order to produce good yields was not available from the 22 in that fall annually. More than 16 in was ineffective. Perusal of twenty years of rainfall records revealed that 25 per cent of the annual rainfall occurred in small isolated showers and was probably quickly lost through evaporation. There is no remedy for this loss. A system of field plats and areas, equipped for measuring water losses, showed another 25 per cent lost to agricultural land through runoff. This accounts for 11 in of the 22-in annual rainfall. Percolation, evaporation, and weed transpiration losses have yet to be accounted for in arriving at the total.

Having in mind the fundamentals of the problem, and realizing that water was the limiting factor in crop production, Texas station workers undertook to develop information that would lead to making available for plant use a larger portion of the annual rainfall, with special reference to conserving that portion lost through runoff. During the first year (1926) at the Spur substation, it was found that losses could be materially reduced through terracing. It was also found that level terraces were much more effective in preventing runoff than were ones having a slope. The following year (1927) additional areas of approximately 10 acres in size were included in the studies. On one of these, level terraces were constructed 15 in high with a vertical distance of 12 in. Ends of the terraces were closed so as to impound all the water. This construction will hold a 6-in rain without allowing for infiltration. These terraces have been in use for five years and there has not been a break or an overflow, nor has there been a cotton plant damaged by excessive moisture.

Saving the entire rainfall on the station clay soils with porous clay subsoils appeared to be a very simple proposition. The question then arose as to whether additional water, secured as runoff from other areas, could be profitably used. The measured runoff from approximately 20 acres of field areas was turned onto a 10-acre area having closed level terraces spaced at a vertical distance of one foot. In addition to holding the entire rainfall 2.52 acre-inches was added the first year without breaking terraces or damaging the growing crop.

At the Spur substation there is a body of land which is comparatively level, and ¼ mile wide and 1 mile long, through which has been passing the runoff from 1200 acres of rolling grassland. During the past winter terraces 30 in high with a vertical fall of 18 in between terraces and with partially closed ends were constructed on this land. These terraces (thirteen in number) were built on the order of the "syrup pan," and water that formerly had to travel a distance of only 1 mile to cross the station properties, now has to flow 6 miles. On this body of land engineering problems, pertaining to the use of runoff in supplemental irrigation, are being studied. Provision has been made to catch as much as 12 acre-inches at a time above some terraces. Drainage is also provided so that water may be turned out during periods of protracted heavy rains in the crop-growing season.

The average yield of seed cotton from field areas during the past three years has been 276 lb per acre on unterraced land having a row gradient of 0.5 per cent; 346 lb per acre for areas contoured but not terraced, and 540 lb per acre from areas having closed level terraces from which there was no runoff. During the three years the cotton yield has been practically doubled through the prevention of runoff. Only one year's results of the use of outside water for supplemental irrigation are available. The application of 2.52 in of water in addition to the rainfall jumped the yield of cotton from 282 to 348 lb per acre in 1930. Land not terraced made only 25 lb per acre during the same dry year.

The Texas station is making a study of a number of the factors involved in water conservation. One of these, and a most perplexing one, is that of equal distribution over terraced fields during periods of torrential rains. Distribution has been a major problem in irrigation under constant water heads, but is much more difficult where storm waters are being used.

Rapidity of infiltration is another major factor involved in the use of soil as a reservoir for storing water during rain periods. Some soils and subsoils are almost impervious to water while in others the downward movement is so free that storage of large quantities is impossible. Closely associated with these problems are those of the water-holding capacity of soils, wilting coefficient, water requirement of crops, and, in the drier section, an almost unwarranted fear of the susceptibility of crops to wet feet. Water conservation and conservation of soil are concomitant. Farm practices that will conserve one will conserve the other and practices that will accelerate the loss of one will accelerate the loss of the other. The nationwide drought of 1930-31 has impressed the American farmer as to the needs for water conservation as forcibly as floods of other years has impressed the need for conserving soil. Semi-arid sections are taking the lead in terracing and contour farming, the object being to make more effective the scant rainfall. Other sections, having heavier annual rainfall, are rapidly learning to conserve water from winter and spring rains for use of the growing crop in dry midsummer.

[1]Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers held at The Stevens, Chicago, December 1931.

[2]Superintendent, Substation No. 7, Texas Agricultural Experiment Station.

(Right) Runoff water held on land for use of crop by means of terraces. This land produced 348 lb of cotton while unterraced land produced only 25 lb. (Extreme right) Type of weir used at Spur (Texas) substation to measure runoff water losses

Some Soil Factors Affecting Erosion[1]

By L. D. Baver[2]

THE CONTROL of erosion is receiving considerable local and national recognition at the present time. Agricultural engineers and soils men are attempting to devise means by which this serious national menace can be eliminated to a considerable extent. There are several new experimental stations in this country solely designed to obtain facts that can be used by the American farmer to keep his soil from eroding. Unfortunately there are many instances in which the efforts of the engineers and soil investigators are being directed somewhat independently of each other.

There are many factors that influence the erosiveness of soils. They may be classified into meteorological, environmental, and inherent. The amount and intensity of the rainfall are perhaps the only significant meteorological factors. The most important environmental factors are (1) the slope and area of the land and (2) the amount and nature of the vegetation (forest, meadow, or crops). The inherent factors are the properties of the soil itself which affect erosion. Several of these properties may be modified to some extent by environmental influences as will be discussed later.

In a very general way, therefore, the factors affecting soil erosion may be summarized in this descriptive equation:

$$E = f\ (R,\ G,\ V,\ S) \qquad [1]$$

in which E is erosion, R a factor depending on the amount and intensity of the rainfall, G a factor depending on the slope and area of the land, V a factor depending on amount and nature of the vegetation, and S a factor depending on the physical properties of the soil.

This general equation is of interest from several points of view. In the first place, there are several important variables, some of which may be controlled and some that are directly uncontrollable. For example, the amount and intensity of the rainfall, the slope of the land, and certain physical properties of the soil cannot be directly controlled. Their effects, however, may be modified indirectly by the use of terracing and other practices. On the other hand, the area of the land, the nature of the vegetation and some of the soil properties can be directly controlled by such practices as terracing, suitable rotations, and so forth.

In the second place, this equation clearly shows that erosion can never be minimized to the greatest extent without the cooperative efforts of the agricultural engineers and the soils men. No equation in mathematics can be solved unless all of the variables are accounted for. This is just as true in the case of soil erosion. The engineer is primarily concerned in solving the first two variables. In other words, he minimizes the effect of rainfall and the slope and area of the land by an efficient system of terracing. The soils man, on the other hand, provides for reducing erosion through good soil management practices. He is primarily concerned with the last two variables. In the final analysis, control of erosion resolves itself into the engineering problem of designing and laying out an efficient system of terraces and the soils problem of providing for a good soil management program to reduce the movement of soil between the terraces.

The requirements of this equation for cooperative solution may be pictured in another way. For example, if we have a uniform soil and the same type of vegetation then the last two variables become constants and erosion is a function of the amount and intensity of the rainfall and the slope and area of the land. Control of erosion is merely a question of handling the runoff water. On the other hand, if we have the same rainfall on different soils with the same slope and area, then erosion will be a function of the type of vegetation and the physical properties of the soil. This fact becomes obvious as one observes differences in erosion on apparently similar soils.

PHYSICAL PROPERTIES OF SOILS AFFECTING EROSION

The different soil factors that influence erosion may be divided into two groups, namely, those which affect runoff and those which affect the movement of soil when runoff occurs.

Absorptive Capacity for Water. Runoff is related primarily to the absorptive capacity of the soil for water and the permeability of the soil profile. The amount of water absorption is necessarily connected with the intensity of the rainfall as well as the absorptive properties of the soil. Consequently, the rate of absorption is probably more important, in most instances, than the amount. The absorptive properties of the soil are related entirely to texture and structure. The rate and amount of absorption increases as the texture of the soil becomes coarser. Sandy soils, for example, absorb water rapidly as compared with clays. Absorption also increases as soils become more granular. A granular clay soil will absorb water much more quickly than the same soil in the non-granulated state. This is due to the relatively high percentage of large pore spaces associated with granulation. Soils become granular as the content of organic matter and lime within the soil increases. It is an established fact that those soils containing much organic matter absorb large amounts of water quite rapidly. Looseness of the soil also enhances absorption. A loose, friable soil will take up more water than one which is compact and smooth on the surface.

Permeability of Soil Profile. Not only must a soil absorb water to prevent runoff, but it must also permit the excess to percolate away to lower layers and be removed through subsurface drainage. The rate of percolation is determined by the texture and structure relationships of the soil. It increases with the coarseness of texture and the extent of granulation. The permeability of the different layers in the soil profile plays an important part in the percolation process. Unless the subsurface horizons are fairly permeable, percolation will be hindered, even though the surface layer is extremely porous. Such a condition is conducive to a large amount of erosion since the surface few inches quickly become saturated with water which permits a rapid removal of soil.

Ease of Dispersion. There can be no movement of soil unless there is runoff. With the same amount and velocity of the runoff, various soils will erode differently depending upon several important soil properties. In the first place, a soil will not erode unless its particles are brought into suspension by the runoff water. In other words, the soil particles must be dispersed in the water in order to be transported. It is obvious, therefore, that the more difficult it is to disperse the particles of a soil, the less will be the erosion. Soils in which the smaller particles are aggregated into granules because of the presence of organic matter and lime are fairly resistant to dispersion and, consequently, should be somewhat resistant to erosion. The lateritic type of soils of tropical and sub-tropical regions are very difficult to disperse and are known to erode relatively little in comparison with the rainfall.

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[1]Paper presented at a session of the Land Reclamation Division of the American Society of Agricultural Engineers during the 26th annual meeting of the Society held at Ohio State University, June 1932. Contribution from the Department of Soils, Missouri Agricultural Experiment Station. Journal Series No. 346.

[2]Assistant professor of soils, University of Missouri.

The velocity of water necessary to cause a soil to become dispersed is much greater than that required to transport a particle after it is in suspension. Therefore, although the transporting power of water is proportional to the sixth power of its velocity, its erosive power will undoubtedly be very different. Unfortunately, there are no data showing the exact effect of the velocity of water upon the erosiveness of soils. It would be expected to vary considerably with the different soils.

Size of Particle. The size of the particle (primary or secondary) also affects the movement of soil under a given velocity of water. It has been shown that the velocity of water necessary to transport the different soil separates is as follows:

Silt	0.25 feet per second
Sand	1.00 feet per second
Gravel	2.00 feet per second

It is obvious that the same runoff on a soil with particles the size of sand will not erode as badly as if its particles were the size of silt. It would take a much smaller runoff to cause erosion on the silty soil. The aggregation of the finer soil particles, which have a low hydraulic value, into larger granules which require a higher velocity to move will result in a decrease in erosion. For example, it is clear that erosion can be hindered to some extent if the silt particles are aggregated into granules the size of gravel. Such a state of granulation exists in soils containing much organic matter and in the soil of the tropics.

Degree of Aggregation. The degree of aggregation (amount of granulation) of a soil, therefore, plays a very important role in the erosiveness of soil. It increases porosity and, consequently, the rate of water absorption and percolation. It decreases the ease of dispersion and makes it more difficult to obtain the soil particles in suspension. It increases the size of the particles so that a higher velocity is required to transport soil.

Erosion as a Function of Soil Properties. As a result of this discussion, Equation 1 can be modified so as to describe the effect of the physical properties of the soil on erosion. If the slope of the land, the rainfall, and the nature of the crop remain constant, the equation reads as follows:

$$\frac{\partial E}{\partial S} = K \qquad [2]$$

which is equivalent to stating that erosion varies with the nature of the soil when all other factors are held constant.

After evaluating the various soil factors, Equation 2 becomes

$$E = \frac{K D}{A P p} \qquad [3]$$

where E is the same as in Equation 1, K a constant of proportion, and D the ease of dispersion. Equation 3 states that erosion is directly proportional to the ease of dispersion, D, and inversely to A, the absorption; P, the permeability; and p, the size of particle.

Equation 3 states that erosion is greater, the easier a soil is dispersed, the lower the water absorption and permeability, and the smaller the size of the particle. The resistance to erosion of tropical soils is readily understood on the basis of this equation. Due to the chemical nature of the soil particle, these soils are highly aggregated and porous. They are extremely difficult to disperse. The entire soil profile has a high absorptive capacity for water. The rate of absorption and percolation is relatively rapid. Although they contain a high percentage of clay, these small particles are aggregated into large granules. Consequently, it is not so surprising to see these soils resist to such a great extent the erosive forces of the tropical cloudbursts. Soils containing large amounts of organic matter and lime act somewhat similarly, although they are not quite as resistant to erosion because aggregation is not as stable as in the tropical type of soil.

Laboratory measurements have confirmed these field observations to a considerable extent. Middleton[3] has studied the physical properties of several so-called erosive and non-erosive soils and has concluded that dispersion and percolation are probably the most important factors influencing erosion. Unpublished data at the University of Missouri show that there is an unquestionable relationship between the erosiveness of soils and the state of aggregation (granulation). The state of aggregation, of course, affects dispersion, absorption, permeability, and the size of the soil particles.

CONTROL OF EROSION BETWEEN TERRACES

Since the physical properties of the soil have such marked influences on erosion, it is apparent that this fact can be utilized in a successful program of erosion control. A good system of soil management should go hand in hand with good terracing. One cannot adequately suffice without the other. Any system of farming which will maintain or build up the organic matter content of the soil will aid in decreasing erosion losses. This is also true if the farming system is so planned as to contain a number of non-cultivated crops. A good rotation, therefore, can accomplish both purposes, provided that a good legume is included in the rotation. Legumes produce much organic matter which in turn improves the physical properties of the soil. Liming is necessary on acid soils to grow legumes. Consequently liming and the use of a rotation with legumes should prove very effective in reducing erosion losses.

Effect of Legume in the Rotation. Results from the erosion experiments at the University of Missouri show quite strikingly that erosion can be reduced by a good system of farming. Part of this data is summarized in Table I. The data in this table were so chosen that the rotation plot and the continuous corn plot could be compared during the months when both were in corn. The soil of both plots is always plowed (spaded) for corn about April 1. Wheat is sown after corn on the rotation plot about October 1. A three-year rotation of corn, wheat, and clover is used. Consequently, any differences in erosion

(Continued on page 57)

[3]Middleton, H. E. Properties of soils which influence soil erosion. U. S. Department of Agriculture Technical Bulletin 170, 1930.

Table I. Runoff and Erosion of Rotation and Continuous Corn Plots During the Growing Season
(Data taken for the months April to October during the years both plots were in corn)

	1917			Annual average for years 1920, 1923, 1926, 1929			
	Runoff, cu ft per acre	Erosion, lb per acre	Erosion per 100 cu ft of runoff	Runoff, cu ft per acre	Erosion, lb per acre	Erosion per 100 cu ft of runoff	Years* to erode 7 in
Plot 6. Rotation of corn, wheat, clover	8,984	10,297	114.5	13,280	6,275	47.2	319
Plot 7. Continuous corn	9,456	8,008	84.2	33,936	29,584	87.1	67.5
Ratio of Plot 7 to Plot 6	1.08	0.9	0.7	2.55	4.7	1.85	

*This assumes that all of the erosion takes place during this six-month period.

Computing the Effective Diameter of a Well Battery by Means of Darcy's Law[1]

By Orville L. Eliason[2] and Willard Gardner[3]

IN THIS ARTICLE an attempt will be made to compute the effective (or equivalent) diameter of a battery of wells penetrating a uniform horizontal stratum of water-bearing gravel bounded above and below by impervious layers, the water pumped from such depth as to insure horizontal movement. The diagrams may suggest implied limitations. It is impossible, for example, to substitute a single well that would be equivalent in all respects and it is admittedly impossible to find such ideal strata in nature.

With the vertical component of velocity absent, the vertical variation in pressure corresponds to the case of no flow, and the water would stand at the same height in piezometric tubes opening into the gravel at any point along a vertical line. In general, however, the height would vary as the tube is moved laterally. One might imagine the surface of the water in the tube tracing out a continuous surface as the tube is moved from point to point in the gravel. The surface thus generated will be characteristic of the gravel stratum for any given state of steady horizontal flow and will be designated the "piezometric surface."

If the reader will undertake to picture the shape of this surface for the case of steady flow from a remote cylindrical source toward the well battery, he will recognize the diagram of Fig 1 as a likely representation of contours over this surface. The term "potential" will be introduced as an alternative expression for "elevation of the hydraulic gradient," and the reader is cautioned to note again with care that there is no vertical variation in the potential in the gravel. This will justify his regarding these closed curves as traces of the vertical equipotential surface in the gravel, extended to intersect the piezometric surface.

In Fig 3 are shown traces of parts of two piezometric surfaces in a vertical plane containing two opposite wells and passing through the axis of the well battery. The one is established by a pump operating in the central well with the water lowered just to the upper boundary of the gravel, and the other by a pump connected to each well of the battery with the water lowered to the horizontal broken line.

As the algebraic development will show, the quantity of water pumped from the central well is the same as that pumped from the battery and the piezometric surfaces intersect at distances remote from the well, but the height of lift is greater in the case of the central well. If, however, the central well is enlarged so that its boundary will intersect the piezometric surface at the elevation of the water in the small wells of the battery, as indicated in the figure, the height of lift becomes the same without disturbing the piezometric surface beyond the well. It has seemed appropriate, therefore, to define the term "equivalent well" as the well which, when pumped to the same depth, will yield the same amount of water as the entire battery with the same potential distribution for the remote potential levels, that is, with practically the same piezometric surface at points remote from the well[4].

In order to compute the diameter it will be necessary to resort to an algebraic development involving an application of Darcy's law and the equation of continuity, leading to an elementary differential equation. An illustrative case of six wells 4 in in diameter on a 40-ft circle, is presented but the development is made somewhat more general. In order to conserve space, summation symbols and other abbreviations have been used, but these need offer but little difficulty. A magnitude α is introduced in Equation A which is a measure of the distance R (Fig 2) in terms of the radius R_a of the well battery. This magnitude, together with the polar coordinate, θ, and the number of wells, n, appears in the product of factors on the right-hand side of equation B, and this equation is introduced for no other purpose than to define the abbreviation symbol $\alpha\,\theta_n$, in which these magnitudes appear as subscripts.

It is hoped that this explanation will aid the reader who has followed the discussion carefully thus far to follow the algebraic development, a part of which is reproduced from a paper, entitled "Drainage of Land Overlying Artesian Basins," published from this laboratory.

The equation for the total flow, Q, passing through an equipotential cylindrical surface of radius, r, into a vertical well penetrating

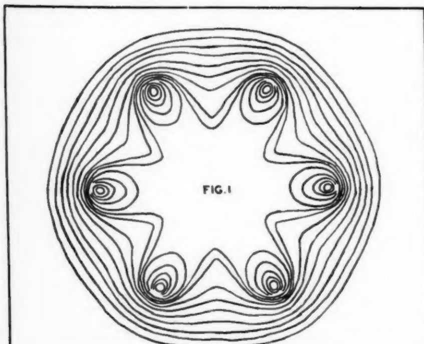
FIG. 1

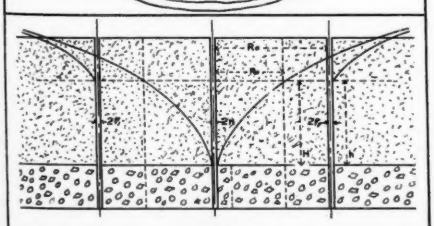
FIG. 3

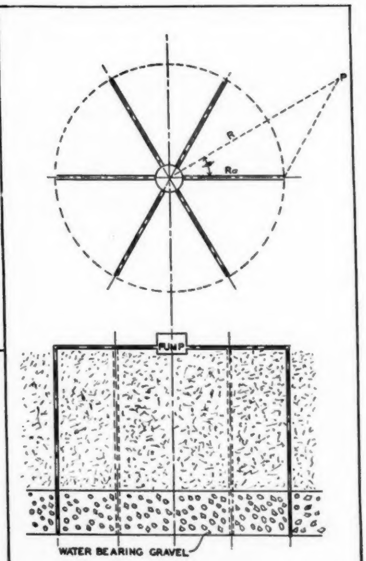

FIG. 2

[1]Contribution from the Department of Physics, Utah Agricultural Experiment Station. Publication authorized by the Director, September 8, 1932. Released for first publication in AGRICULTURAL ENGINEERING.

[2]Graduate student, Utah Agricultural Experiment Station.

[3]Physicist, Utah Agricultural Experiment Station.

[4]The use of the term "remote" would seem to leave the definition incomplete. A careful study of the mathematical development will reveal the fact that as the remote distance becomes larger and larger the diameter of the equivalent well tends toward a limiting value, and it is this limiting value for which the equations have been solved.

completely the water-bearing stratum of thickness, l, is given by

$$Q = 2\pi r l f \rho v \qquad [1]$$

in which f is a porosity factor, v the velocity, and ρ the density of the liquid.

Darcy's law may be written for this case

$$v = k\ (dp \div dr) \qquad [2]$$

p being the potential[5].

Eliminating v from these two equations and integrating the resulting expression between the limits p and p_o, and R and R_1, leads to

$$p - p_o = [Q \div (2\pi \rho l k f)]\ ln\ (R \div R_1) \qquad [3]$$

The constant quantity within the brackets may be replaced by C, and Equation 3 written concisely

$$p - p_o = C\ ln\ (R \div R_1) \qquad [4]$$

For each of the several wells of the battery an equation of this form would express the potential difference in terms of the distance from the well provided the other wells did not interfere. Adequate account is taken, however, of such interference by superimposing the individual effects of the respective wells. Thus

$$p - p_o = \sum_{i=1}^{i=n} p_i = (C \div n) \sum_{i=1}^{i=n} ln\ (r \div r_1) \qquad [5]$$

where p_i represents the contribution of pressure "due" to the i'th well of the n wells of radius r_1 comprising the battery, and r the distance from this well to the point where the pressure is estimated.

If R and θ are used for the polar coordinates of the point P, and R_a for the radius of the well battery, a reference to the diagram of Fig 2 will make clear the meaning of the following equation

$$r = \sqrt{R^2 + R_a^2 - 2RR_a \cos \theta} \qquad [6]$$

Eliminating r from Equation 5 by means of this equation, we have

$$p - p_o = (C \div n) \sum_{i=1}^{i=n} ln \frac{\sqrt{R^2 + R_a^2 - 2RR_a \cos (\theta + \frac{i\,2\pi}{n})}}{r_1} \qquad [7]$$

It will prove advantageous, as well as somewhat more general, to introduce explicitly the elevation h of the variable point on the piezometric surface, from the upper plane boundary of the gravel stratum as a base, to replace $p - p_o$. As will appear from inspection of equations 2 and 3 and also from the form of Equation 7, the constant C may be endowed with such appropriate dimensions as to justify rewriting Equation 7 thus

$$h = (C \div n) \sum_{i=1}^{i=n} ln \frac{\sqrt{R^2 + R_a^2 - 2RR_a \cos (\theta + \frac{i\,2\pi}{n})}}{r_1} \qquad [8]$$

If we take the axis of the central well with its intersection with the upper plane boundary of the gravel, as a reference frame, we shall recognize this as the equation of the piezometric surface of the well battery. Similarly, we may write the equation of the piezometric surface for the equivalent single well

$$H = C\ ln\ (R \div R_e) + h' \qquad [9]$$

where R_e is the radius of the equivalent well and h' ($=H'$) is the elevation of the water surface in the small wells. (Fig 3).

Equations 8 and 9 furnish a sufficient basis from which to compute the equivalent radius R_e. It is necessary only to equate the right-hand members for large values of R, substituting $\theta = O$, in order to obtain a relation between R_e, R_a, r_1, n, and h'. Equation 8 may then be solved for h' by substituting R_a for R, giving finally the value of R_e in terms of R_a, r_1 and n.

The method to be adopted in carrying out this detail is a matter of discretion. The following procedure was used:

As previously explained, the quantity α, defined thus

$$R = \alpha R_a \qquad [A]$$

was introduced, leading to the equation

$$h = (C \div n) \left[\sum_{i=1}^{i=n} \tfrac{1}{2}\ ln \left\{ R_a^2 (1 + \alpha^2 - 2\alpha \cos [\theta + \frac{i\,2\pi}{n}]) \right\} - n\ ln\ r_1 \right] \qquad [10]$$

It was found convenient also to introduce an abbreviation for a finite product of trigonometric terms arising from the summation of logarithmic expressions in Equation 10

$$G_{\alpha\theta_n} = \left[1 + \alpha^2 - 2\alpha \cos (\theta + \frac{2\pi}{n}) \right] [\,..\,]\,..\,[\,..\,]\,.. \qquad [B]$$

It is possible to compute the value of this expression for various values of α, θ, and n, but it becomes necessary to compute it only for $\alpha = (R_a + r_1) \div R_a$, $\theta = O$, with any arbitrary choice of n. It is helpful to observe that for large values of α the right-hand member reduces to α^{2n}.

If we introduce the symbol β defined thus

$$\beta = \frac{R_a + r_1}{R_a} \qquad [C]$$

the final formula takes the compact form

$$R_e = (G_{\beta O n})^{1 \div 2n} R_a \qquad [11]$$

This was solved for the special case,

$$R_a = 20 \text{ ft}$$
$$r_1 = 1/6 \text{ ft}$$
$$n = 6$$

giving for the corresponding equivalent radius, $R_e = 12$ ft.

It is to be observed, therefore, that the solution of this problem on the basis of Darcy's law reduces to a problem in elementary mathematics, and it is hoped that engineers may find it useful.

[5]With appropriate choice of units the term "pressure" may be used interchangeably with "potential," and for a thin stratum the gravity potential is uniform, permitting the interpretation of p as the pressure.

Kansans Try Terracing

By John S. Glass[1]

OUR job in introducing the practice of terracing in Kansas was primarily for the purpose of saving soil. Climatic conditions are varied; soil formations of many descriptions exist; crops produced differ decidedly in various sections of the state, and the rainfall swings spasmodically from one extreme to the other. We are relatively sure of one thing. We may get but little rain during the growing season, but when it comes it will come as a tropical torrent. Four, five, six and even eight-inch rains that fall in a very short time subject cultivated areas to severe damage by washing.

We had just a start in 1928, with demonstrations on about 1000 acres of farm land. With these demonstrations as a background we began training leaders to handle the job in their local communities. Four hundred eighty-six men attended the leader training schools in 1931. Each of these men then did a job for himself, and two hundred eighty of them helped a neighbor. This group made it possible for us to terrace 22,000 acres in 1931, bringing our total terraced area to 42,000 acres in the state.

[1]Extension agricultural engineer, Kansas State College. Mem. A.S.A.E.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Requests for copies of publications abstracted should be addressed direct to the publisher.

Developments in Irrigation Practices, H. A. Wadsworth and H. R. Shaw (Hawaiian Sugar Planters' Association [Honolulu] Proceedings 51 (1931), pp. 507-559, figs. 40).—A description is given of the more recent developments in irrigation practices for sugar cane in the Hawaiian Islands, and the results of experiments with some of these are reported.

It is pointed out that widespread developments in methods of irrigation designed for greater economy of labor and water have taken place on Hawaiian plantations during the past two years. Although many of the methods are not universally adaptable, the results gained in labor economy, water conservation, improved moisture distribution, and economical cultivation in many localities warrant careful scrutiny and trial.

Certain modifications of the Hawaiian contour system have proved economical in operation, are readily installed in ratoon fields, and are adapted to a wide range in terrain. Several cut-line methods which are under trial are here described. The Koloa system has been given extensive trial on many plantations. In spite of difficulties encountered in certain topography and on certain soil types, the method in general seems to be successful and popular. Long-line irrigation shows promise in many localities where it has been installed. The use of mechanical cultivation in conjunction with long-line irrigation appears to be a decided advantage in favor of the method. The border method of irrigation is proving particularly effective on most lands carrying slopes no greater than about 2 ft per 100 and which are difficult to irrigate by the contour method. Plantations using the border method have greatly increased the area irrigated per man-day, but have found a somewhat greater consumption of water than by the contour method.

Comparatively little ditch lining has been completed on Hawaiian plantations during the past year. Water measurement on many plantations is becoming an important unit in the system of distribution and application of irrigation water. The Parshall measuring flume has become the standard device for measuring water in supply and straight ditches on many plantations. There is a need for a simple device for measuring the discharge of water in ditches of low gradient.

Further Experiments in Electrofarming (United Provinces of Agra and Oudh, Department of Agriculture [Allahabad, India] Bulletin 61 (1932), pp. IX + 37, pls. 11).—Following a brief discussion of simple methods of electrical treatment of plants and seeds by the hydro electric grid area and by radio-magnetic equipment, experiments on different treatments of plants and seeds are reported.

Strawberry plants treated with a high-tension spark showed improvement in growth and fruit. Plants placed in a radio-magnetic cradle showed noticeable improvement in growth, tillering, fruit, and resistance to virus diseases. Twenty branches with ripening berries caught in a loop or collar of soft-iron magnet yielded earlier, better, and brighter fruit than the remaining branches of the same plant.

The germination and growth of 20 different kinds of flower seeds were forced up to 30 per cent over the controls by radio-magnetic treatment of the bed. X-rayed cotton and barley seeds gave the best results as regards germination, growth, and maturity in comparative tests of X-ray, violet ray, ultra-violet ray, and radio-magnetic treatments. The ultra-violet ray treatment reduced the germination period from 7 to 4 days. X-ray and radio-magnetic cradle treatments gave the best results as regards germination, growth, maturity, and yield of miscellaneous hill crops, including beans, millet, rice, and peas.

Leaf curl in tomatoes appears to have been suppressed under experimental conditions by means of atmospheric electricity. The efficacy of electrocultural treatment of sugar can in resisting attacks of white ants was demonstrated, and the slow continuous treatment received in the radio-magnetic bed was shown to increase the size of goseberry plants and the yield of fruit. Bamboo seedlings also were found to respond actively to electrocultural treatment.

A symposium of opinions on the general subject of the electrical treatment of crops is included.

House Insulation: Its Economies and Application (Washington: U. S. Department of Commerce, National Committee on Wood Utilization, 1931, pp. V + 52, figs. 34).—This is a report of the subcommittee on house insulation, its economies and application, of the National Committee on Wood Utilization, prepared by R. E. Backstrom. It contains both technical and popular information on building inulation for the use of designers, builders, and owners, and includes sections on types of insulation; insulation of walls, floors, and roofs; thickness of insulation to use; methods of applying insulating materials; insulation of the house already built; and cost of insulating. Appendixes deal with weatherproofing, fuel savings effected by insulation and weatherproofing, examples of the cost of insulating, and bibliography.

An Investigation of the Performance Characteristics of Reinforced Brick Masonry Slabs, J. W. Whittemore and P. S. Dear (Virginia Polytechnic Institute, Engineering Experiment Station [Blacksburg] Bulletin 9 (1932), pp. 63, figs. 21).—In studies of the effect of the physical properties of shale and clay bricks on the performance characteristics of reinforced brickwork slabs, 5 reinforced slabs each of hard-burned, medium burned, and soft-burned clay and shale brick, making a total of 30 slabs, were tested.

In general, the performance characteristics of the shale brick slabs were slightly superior to the performance characteristics of the clay brick slabs. Slabs constructed from the softer fired bricks performed better under load than those constructed from the harder fired bricks. In practically every case during the testing of the 30 slabs, the initial failure occurred before the allowable deflection was reached. The instantaneous recovery performance of the slabs, even well past the design load, was very favorable. The deflection performance of the slabs was also very good. These facts warrant the conclusion that all slabs tested during the investigation possessed ample stiffness until well past the design load.

Under ordinary circumstances of slab design, the compressixe strength and the transverse strength of the individual bricks are apparently of minor importance in the performance of the slab. As a general rule, any well-fired brick has sufficient strength to introduce an ample factor of safety in respect to the ultimate strength of the brick masonry.

In reinforced brick masonry construction, the percentage of absorption of the individual brick assumes the greatest importance of the usually determined physical properties of the brick. The strength of adhesion of mortar to brick and of mortar to steel are very important items.

During the investigation it was noted that the best slab performances were associated with bricks having the highest percentage of absorption and having the greatest strength of adhesion of mortar to brick. This indicates that there is a direct relationship between absorption and mortar joint strength.

Surface characteristics and texture of the individual bricks are important factors in the performance of reinforced brick masonry, since they influence mortar joint strength. Bricks with roughened surfaces exposed to union with the mortar greatly aid mortar joint strength and slab performance. Reinforced brick masonry slabs constructed by grounding the mortar joints are apparently well able to withstand design loads. The widely used 1-1-6 mortar mix is adaptable to the construction of slabs by grouting the mortar joints. Though plain round reinforcing rods are adaptable to reinforced brick masonry slab construction, it is the opinion of the investigators that deformed rods would be more desirable since they would promote greater bond strength between the mortar and the steel.

All bricks should be wetted before use in reinforced brick masonry. The degree of wetting should be governed by the absorption of the individual bricks. Bricks with high absorption should be wetted more thoroughly than bricks with low absorption in order to prevent the destruction of the mortar strength by decreasing the water-cement ratio. Quality of workmanship is an important factor in slab performance.

The actual stresses in steel and brickwork, as experimentally determined, are well below those circulated by reinforced concrete design formulas. It is evident that the formulas of reinforced concrete are adaptable, with slight modifications, to reinforced brick masonry design.

Reinforced brick masonry slabs perform in a very similar manner to reinforced concrete slabs and are, therefore, theoretically and experimentally practicable.

A short bibliography is included.

The Effect of Humidity on Engine Power at Altitude, D. B. Brooks and E. A. Garlock (National Advisory Committee Aeronautics [Washington] Rpt. 426 (1932), pp. 9, figs. 5).—Tests conducted at the U. S. Department of Commerce Bureau of Standards are reported in which it was found that the action of humidity on engine performance is not affected by change of air pressure or air temperature. The effect of humidity is to decrease engine indicated power in proportion to the concomitant decrease of dry-air pressure. The maximum obtainable indicated power of an engine under any conditions is directly proportional to its mass rate of consumption of oxygen under these conditions. Over the range covered by these tests the dry-air-fuel ratio for maximum power is invariant with altitude.

An appendix gives correlation coefficients.

The Use of Electricity in Horticulture, C. A. C. Brown (Journal of the Ministry of Agriculture [London], 38 (1931), No. 2, pp. 132-137).—In a contribution from the Institute of Agricultural Engineering of the University of Oxford, a survey is presented

(Continued on page 62)

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Pneumatic Tires on the Soil

IN BOTH the educational and industrial wings of our profession the pneumatic tractor tire is mingled promise and challenge. It reminds us sharply that ours is largely the engineering of adaptation and application. In the face of such enthusiasm as is aroused by the spectacular performance of pneumatic-tired tractors, it takes a measure of courage to maintain that critical skepticism which makes engineering advance sound and sure.

An immediate challenge is to determine the types of soil, including every condition of soil on which the system of farming may require a tractor to be used, to which rubber-tired tractors are suited. The final answer will be actual experience throughout the life of the tractor. For immediate appraisal of probable performance we may find help in the dynamic properties of soils as defined by Professor M. L. Nichols and colleagues. Indeed, there may be suspected a substantial relation between the colloidal characteristics of a soil and its adaptation to soft-rubber traction.

This is in line with experience on some soils low in organic matter. Taking into account also farm size and crop characteristics, there is promise that the pneumatic tire will open up a new zone of tractor usage, with a new type of tractor. Perhaps this will have more immediate significance than displacement of other types of traction member.

For nearly a century after invention of the reaper and of the steel plow, speed as a factor in the design and operation of field machinery remained almost a constant, established by the gait of the horse. In the latter part of the century, to be sure, came the tractor and a fractional increase in field speeds. Not only did traction efficiency fall off prohibitively with increased speed, but among the basic implements of tillage there were no designs capable of efficient work at higher speeds. Created as they were by a century of empirical development, there could be expected no sudden adaptation to materially higher speeds.

With its amoeboid manner of soil contact the pneumatic tire has reduced soil disturbance to a minimum and made tractive efficiency largely independent of speed. It promises to change field speed from a constant to a wide variable. In effect it introduces another dimension into the calculations of the designer, especially he who deals with soil-working members.

Fortunately — and again the name of Professor Nichols comes to mind, though he would cite sundry others — basic research into soil dynamics has reached a point where speed can be definitely computed into design. We may expect the implement designer to be reasonably prompt in taking advantage of the multiplied speeds promised by the tractor and tire engineers.

Rubber traction may reopen the whole question of weight-to-pull relationship in the tractor, but it seems likely that power, being proportional to speed, will be demanded in far greater measure than weight, placing emphasis on engines of high specific power, and on weight-saving construction throughout the tractor. Certainly in drawn machines lightness will be at a premium, while the dynamic stresses implied by speed will demand higher elastic limits and ultimate strengths.

All of this points not only toward new designs, but also to lighter and stronger structural materials. It suggests metals of better wearing quality for soil-working surfaces. It puts new emphasis on sureness and quickness of lubrication, and widens the field for anti-friction bearings.

It should be noted, too, that full fruition of rubber tires on the tractor implies their use also on at least some of the drawn machines. Indeed, it is history that pneumatic tires were used on corn-pickers to make operation possible in soil conditions where the same tires might have failed on a tractor. Their cushioning qualities, their load-carrying ability, and their low rolling resistance may earn applications where they would be ruled out for traction.

Perhaps it is just as well that so alluring a development as the pneumatic tractor tire should make its debut in a time when production of farm machinery is at low ebb, yet with research and invention being pushed at accelerated pace, and all under sharpest scrutiny from the economic angle. We may hope for enough of pessimism to guard against a repetition of the war-time tractor boom. In any case the pneumatic tire is so interlocked with soil dynamics, with implement and machine design, with farm methods and management, as to emphasize once more that, despite its specialized divisions, agricultural engineering is a unified and strongly coherent profession.

W. B. JONES.

Improvement in Education

WHAT is the final justification or objective of agricultural engineering? Is it not, as in other branches of engineering, helping people to achieve more fully, with less waste of time and effort the things for which they live and work? Is it not, in other words, the conservation of human values?

And does it not impose upon its teachers a need of unusual pedagogic foresight and efficiency? Foresight as to probable future opportunities for the requirements of agricultural engineers? Foresight as the possibilities and probable capacities of their students? Efficiency in utilization of the students' time and energy in uncovering and developing their latent capacities? Should they not, as teachers of efficiency, be leaders in efficient teaching?

Should not agricultural engineering education be guided with broad vision by all that is best in related engineering and agricultural sciences, and in educational methods?

Should agricultural engineering teachers not feel a responsibility—to the individuals taught, to the public, to the agricultural engineering profession, and to the teaching profession—for conservation of human values in their process of education as well as in the processes of agriculture?

In order that agricultural engineering teaching may continually improve, the A.S.A.E. College Division has a Committee on Agricultural Engineering Education. It stimulates, concentrates, coordinates, and gives continuity to improvement work. It has reached a stage in its work which calls for and warrants the hearty, active support of every member of the College Division.

Building on the foundation set up by the Committee during 1931-32, the present general chairman, C. O. Reed, has pictured the problems before the committee—before all teachers of agricultural engineering, in fact—to the best of his ability from his individual viewpoint as one agricultural engineering teacher of wide experience. He points out the important relationship between viewpoint, policies, objectives, methods, and measurements.

This picture, sent to each college agricultural engineering department in the form of a mimeographed presentation, includes a suggested procedure. It asks a reading of the presentation by all teachers, both resident and extension, to be followed by departmental conferences. It invites comment, criticism, and information on what has been done in the department by way of improving its teaching. It is an open invitation to every agricultural engineering teacher to cooperate with the Committee.

This presentation is not a mere expedient to help lagging teachers and departments justify themselves before administrators and legislative committees wielding the public-economy axe. It is a call for a showdown and further development of educational leadership by agricultural engineering teachers; for progress in the conservation of the human values placed in their trust.

Just Between Ourselves

DEPLORING the foisting of numerous unrelated administrative functions upon the U. S. Department of Agriculture, and the state of agricultural research as "The Forgotten Job," J. Sidney Cates, in the January "The Country Gentleman," quotes Dr. Karl J. Kellerman on the value of knowledge as produced by research: "When it comes to economy it should be born in mind that there is nothing else quite so expensive as ignorance." Enlarging upon this philosophy, not new to agricultural engineers, and citing neglected research opportunities, Author Cates says, in part: "....... Congress has not yet financed a research program looking to analyzing this whole matter of soil manipulation, a job which costs the farmers of the country more than anything else having to do with farming. Until this is done, we will not know what constitutes good plowing, or whether present plowing machinery should be modified radically.....

"The new acid-soil legumes seem to portend radical changes in cotton farming, but there has been organized no research and development work looking to hastening the fulfillment of this promise. Maybe we could produce cotton so good and so cheap that the rest of the world would quit trying to compete with us. Maybe if it continued cheap, consumption would go up and up, thus vastly expanding the business. If the South is not to take defeat lying down, research organized and backed more comprehensively than ever before would seem to be the only answer."

* * * * *

V. B. HART, in his paper published in the January 1933 issue, joins the growing body of agricultural economists and farm managers who have gone on record as recognizing price conditions for what they are and as seeing hope in agricultural-engineering attempts to lower farm production costs. To repeat some of his own words for emphasis: "...... The safest procedure for a farmer to follow is to expect the continuance of pre-war or below pre-war prices .... there is still a great need for saving on labor by increasing the production per hour of labor. One of the easiest ways of doing this is to increase the production per animal and per acre....... One way of increasing the production per hour of labor is to increase the efficiency of machinery .... one of the most important factors affecting the cost of machinery per acre is the size of the business or number of acres on which the machine is used..... One way of increasing the efficiency of machinery is by making sure that it is in shape to give more service. We need still more schools and short-courses on putting machinery into condition so that it can cover a larger number of acres before wearing out or breaking down........ One place where the agricultural engineer may be going to fit into the picture is by showing farmers and rural highway superintendents how to build and maintain inexpensive roads with local labor and materials .... he (the farmer) is especially anxious for the kind of information and advice that will help him get enough cash to cover his absolutely necessary business and personal expenses, and this last want is the challenge of the times to the agricultural engineer ...."

Some Soil Factors Affecting Erosion

(Continued from page 52)

between the two plots during these six months, April 1 to October 1, are due primarily to the effect of the legume in the rotation. It is interesting to note that the runoff and loss of soil from both plots was about similar at the beginning of the experiment. As a matter of fact, the rotation plot eroded slightly more during the first year. A striking difference, however, now exists in the erosiveness of these two plots when both are in corn. Runoff on the continuous corn plot is slightly more than two and one-half times greater than on the rotation plot. This shows that the incorporation of the legume has increased the absorptive capacity of the soil for water. Percolation has also been increased to some extent. Erosion is almost four and three-fourths times greater under continuous corn than under a rotation system of farming. Erosion per unit runoff is almost twice as much on the continuous corn plot. These data show that organic matter has increased the resistance to erosion when runoff takes place. This is primarily due to its effect upon the granulation of the soil. The more abundant root system of a better corn crop on the rotation plot may have had some influence, although the data indicate that it is small. If erosion only took place during the six months when these two plots were in corn, it would take 319 years to erode the surface seven inches if a rotation were used as compared with 67.5 years with continuous corn.

These data become more striking when one considers these erosion plots as representing plots between terraces. If one considers the upper and lower ends of the plots as being terraces, the terrace interval would be 3.3 ft. This interval is about the same as that on the same soil in an adjacent terraced field where the interval varies from 3.5 to 4.5 ft, depending upon the steepness of slope. These data, therefore, should be interpreted as representing movement of soil between terraces. They point out most vividly the need for proper soil management practices on terraced land to further minimize erosion losses. Where incorrect farming practices are being followed one should expect as much erosion with a close spacing of terraces as with a wider spacing where a good soil management program was being followed. This concept is not generally recognized but should be considered in terracing practices.

Efficiency in Erosion Control. On the basis of this discussion it is obvious that on land suffering from considerable erosion an efficient program of erosion control resolves itself into the simultaneous use of a good system of terracing and correct soil management practices. One is not entirely effective without the other. A correct system of soil management will reduce the movement of soil between terraces which should lengthen the time between the reworking of the terraces as well as causing a much higher state of fertility between them. Even though eroded soil is caught by the terrace and prevented from leaving the field, it would be much better, from a fertility standpoint, if this soil could be prevented from moving between the terraces to a considerable extent.

When the American farmer is thoroughly awakened to the seriousness of erosion losses on his farm and when the agricultural engineer and soils man, as a cooperative unit, offer to him the best possible means for reducing these losses to a minimum, then will we have efficiency in erosion control.

A.S.A.E. and Related Activities

Perry Heads Pacific Coast Section

RUSSELL LAWRENCE PERRY, assistant professor of agricultural engineering University of California, was selected chairman of the Pacific Coast Section of the American Society of Agricultural Engineers at its eleventh yearly meeting held at the Hotel Sainte Claire, San Jose, California, January 20, 1933. This past year Mr. Perry has been serving as vice-chairman of the Section, and presided at the meeting of the Section just held, in the absence of the chairman.

Other officers of the Section elected at this meeting include Max E. Cook, farmstead engineer, Pacific Lumber Company, as first vice-chairman; L. J. Smith, professor of agricultural engineering, State College of Washington, as second vice-chairman; F. E. Price, agricultural engineer, Oregon State College, as third vice-chairman; and Walter E. Packard, consulting engineer, a member of the Executive Committee. Walter W. Weir, associate drainage engineer, University of California, who has served the Section so ably and efficiently for several years as secretary-treasurer, was again re-elected to that office. The Nominating Committee elected consists of O. V. P. Stout, chairman, A. M. Frost, and J. C. Marr.

In addition to the technical program previously announced in these columns, the Section held a business session, in which, in addition to the election of officers, considerable time was devoted to the reports of the various committees in charge of preparations for the 1934 annual meeting of the Society at Asilomar, California. These reports indicated that considerable progress is being made in preparation of that meeting.

An exceedingly interesting technical program was offered by the Section at this meeting, outstanding papers of which will appear in subsequent issues of AGRICULTURAL ENGINEERING.

Fletcher on American Engineering Council

LEONARD J. FLETCHER, past-president of the American Society of Agricultural Engineers, attended the annual meeting of American Engineering Council in Washington, January 13 and 14, as official representative of the Society. R. W. Trullinger, another past president, is the Society's alternate representative on A.E.C. Mr. Fletcher and Mr. Trullinger assumed their offices as representative and alternate, respectively, on January 1, and will continue to represent the Society in these capacities until their successors are appointed.

The meeting this year of American Engineering Council was attended by more than fifty representatives of the national, state, and local engineering societies which comprise that organization. In the election of officers John F. Coleman of New Orleans, a past-president of the American Society of Civil Engineers, and William R. Woodbury of Duluth, past-president of the Minnesota Association of Engineering and Architectural Societies, were elected vice-presidents for a two-year's term. Mr. Farley Osgood was re-elected as treasurer, and Mr. E. J. Hammond, president of A.S.C.E., was re-elected chairman of the finance committee.

A special committee of A.E.C reported an investigation of the water resources functions of the federal government, which among other things recommend the immediate establishment of an interdepartmental board of water resources investigations for the various functions of the federal agencies dealing with water resources.

The Assembly of the A.E.C. considered and expressed its position on several important policies relating to public affairs of engineering interest. The recommendation that A.E.C. urge engineering groups in each state to actively participate with others in the endeavor to have the proposed Uniform Mechanics Lein Act adopted by the several state legislatures was approved. A resolution relating to the advance of topographical mapping through cooperation with state officials was adopted, and officers of A.E.C. were authorized to take steps looking toward the consummation of such cooperation.

The Assembly was advised of the progress made by the federal employment stabilization board and the possibility for extending this work to the several states, and adopted a recommendation that A.E.C. cooperate in an effort to bring to the attention of state legislatures the advisabilty of setting up such a local employment stabilization board to permit advanced planning of public works. The Assembly also expressed approval of the better housing movement, and authorized the officers of the A.E.C. to bring this movement to the attention of its state committees on engineers and employment for their consideration and participation as opportunity might present itself.

Drainage Congress Meets this Month

THE TWENTY-SECOND annual session of the National Drainage, Conservation and Flood Control Congress will he held at the Deshler-Wallick Hotel, Columbus, Ohio, February 15, 16, and 17. The forenoon program of the first day's session will consist of addresses of general interest, while the afternoon session will be devoted exclusively to the subject of the utilization of sub-marginal lands, including papers on soil erosion control. The evening session will be devoted to the discussion of the relation of forestry to conservation. The program of the second day will be devoted to a variety of subjects, including conservation of lakes, underground water, recreation and its relation to conservation, and the report of the work of the national land use committees. The last day's program will include educational tours to the O'-Shaughnessy Dam, a study of water supply and drainage problems around Dayton, and a visit to various engineering projects in the vicinity of Dayton and Miami.

Several members of the American Society of Agricultural Engineers will take part in this program. Among these are the president of the Congress, E. V. Willard, state drainage engineer of Minnesota. Lewis A. Jones, chief, division of drainage and soil erosion control. U. S. D. A. Bureau of Agricultural Engineering, will present a paper on the subject of soil erosion control. Virgil Overholt, agricultural engineer, Ohio State University, will present a paper upon the general heading of the relationship of forestry to conservation. Mr. Willard will discuss the subject of conservation of lakes. Dr. Elwood Meade, commissioner of reclamation, U. S. Department of the Interior, and an honorary member of A.S.A.E., will deliver an address at the annual banquet on the subject of the construction progress on the Hoover Dam.

Fertilizer Application Report

THE PROCEEDINGS of the eighth annual meeting of the Joint Committee on Fertilizer Application, held at the Raleigh Hotel, Washington, D. C., November 16, 1932, have been prepared in mimeographed form and are being distributed by the National Fertilizer Association, Washington, D. C. The greater part of the attention of the Committee at this meeting was devoted to the investigations of the machine application of fertilizers being carried on in various

states and for various crop requirements.

The Joint Committee on Fertilizer Application consists of representatives from the American Society of Agronomy, National Association of Farm Equipment Manufacturers, National Fertilizer Association, and the American Society of Agricultural Engineers. The last named organization is represented by C. O. Reed (chairman), C. J. Allen, E. V. Collins, G. A. Cummings, E. R. Gross, J. O Smith, and C. H. White.

A.E.C. Resolution on "Technocracy"

The following is the resolution on technocracy adopted January 14, 1933, by the assembly of American Engineering Council, during its annual meeting in Washington:

"The statements of a group of men organized under the name 'Technocracy' have received wide publicity through the press by reason of startling predictions which involve a complete overturn in our economic structure. These pronouncements, circulated as coming from engineers, have led to the belief that they represent responsible engineering thought.

"Many requests for information on Technocracy have come to American Engineering Council, which is the representative of national, regional, and local engineering societies in the United States. The Council has endeavored to obtain from the promoters of the movement an authoritative statement of their findings and their program. It is significant that no information could be obtained beyond what has appeared in the press.

"The accepted practice among engineers of presenting new developments to some engineering society for critical study and discussion has not been followed. The data and statistics brought forward in magazine and newspaper articles as a basis for speculative claims are open to question; some of the findings have been discredited or disproved by other investigations.

"These statements and conclusions may have a serious effect through undermining public confidence in our present civilization; and they hold out an unwarranted promise of a quick solution of economic ills. The method of presentation has been marked by exaggerated, intolerant, and extravagant claims. They have capitalized the fears, miseries, and uncertainties due to the depression and have proposed a control which is, in effect, class dictatorship.

"Contrary to these claims, there is nothing inherent in technical improvement which entails economic and social maladjustments. Indeed, technology offers the only possible basis for continuing material progress. The volume of goods produced, distributed, and consumed during the years 1928 and 1929 was not excessive. That volume may and should be surpassed upon the return of prosperity.

"The alleged unmanageability of a machine economy has not been proven. Its dislocations are traceable to improper and unskilled use rather than to inherently harmful characteristics. Complete replacement of men by the machine is precluded by the law of diminishing returns. Instances are increasingly in evidence. Contrary to the pronouncements of Technocracy, applied science holds the promise of better things to come in a society which fearlessly and intelligently meets its problems. It is the considered opinion of American Engineering Council that our present economic structure contains within itself the possibilities of progressive improvement and of the attainment of higher standards of living."

Personals of ASAE Members

Wallace Ashby, chief, division of structures, and **M. C. Betts**, chief, division of plans and service, Bureau of Agricultural Engineering, U. S. Department of Agriculture, are joint authors of Leaflet No 87, entitled "Wind-Resistance Construction of Farm Buildings," recently issued by the U. S. Department of Agriculture.

Dean W. Bloodgood, associate irrigation engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture, is author of Bulletin No 205, entitled "The Effect of the Frequency of Irrigation on Potatoes Grown in Mimbres Valley, New Mexico," recently issued by the New Mexico Agricultural Experiment Station.

C. H. Dencker, formerly associated with the Prussian Agricultural Research Institute, was appointed October 1 as head of the Department of Agricultural Engineering of the Agricultural College in Berlin. He has also been made director of the German tractor testing field in Bornim near Berlin.

H. L. Garver, investigator in farm electricity, Washington Agricultural Experiment Station, is one of the authors of Bulletin No 216, entitled "Irrigation of Orchards by Sprinkling," recently issued by that station.

L. G. Heimpel, professor of agricultural engineering, Macdonald College of McGill University (Canada), is author of Farmers' Bulletin No 5, entitled "Dairy Barn Ventilation," recently issued by that institution.

B. B. Robb, professor of agricultural engineering, Cornell University, and **J. L. Strahan**, consulting agricultural engineer, are joint authors of Cornell Extension Bulletin No. 247, entitled "Ice on the Farm," recently published by the New York State College of Agriculture at Cornell University, Ithaca, N. Y.

L. J. Smith, secretary, and **H. L. Garver**, investigator, of the Washington Committee on the Relation of Electricity to Agriculture, recently issued in mimeograph form, a rather exhaustive progress report of investigations of the various uses of electricity on the farms of Washington for the year 1932.

Necrology

FREDERICK EDWARD GOETZ, associate mechanical engineer, engineering experiment station, Colorado Agricultural College, passed away December 22, 1932. He had been a member of the Society since January 1930.

Mr. Goetz was born at Detroit, Michigan, in 1904, and at the age of three moved with his parents to the Province of Saskatchewan. He received his bachelor's degree in agricultural engineering at the University of Saskatchewan in 1928, and his master's degree in 1930 from Kansas State College. He accepted in October 1930 the position which he held at the time of his passing. He is survived by his parents, one brother, and three sisters, all of Dundurn, Saskatchewan.

New ASAE Members

F. E. Hardisty, associate agricultural engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture (Mail) Box 413, Zanesville, Ohio.

Henry A. Magnuson, assistant architectural engineer, division of plans and service, Bureau of Agricultural Engineering, U. S. Department of Agriculture, Washington, D. C. (Mail) Apt. 111, 1620 Fuller St., N. W.

Transfer of Grade

C. F. Miller, agricultural engineer, National Lumber Manufacturers Association, Room 2017, Conway Building, Chicago, Ill.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the January issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

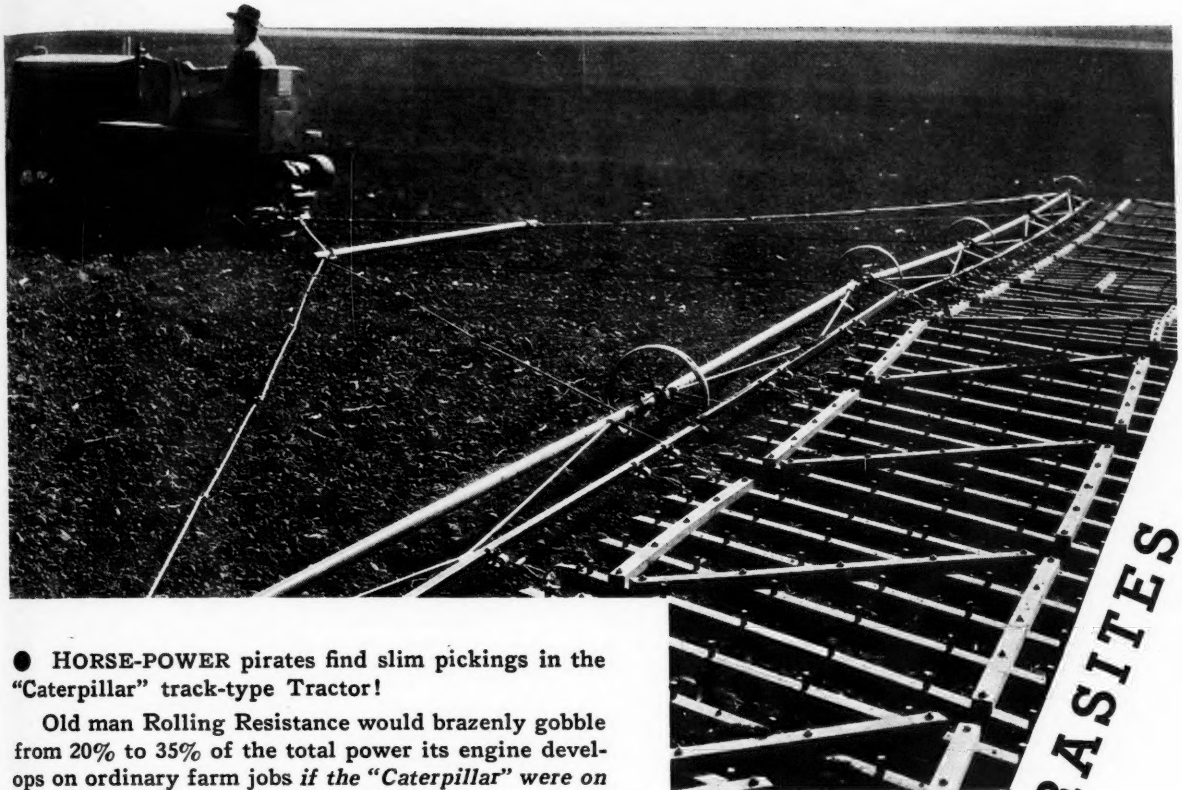
Samuel W. Gray, sales engineer, Wheeler-Schebler Carburetor Co., Flint, Mich.

Frank C. Hughes, experimental engineer, Minneapolis-Moline Power Implement Co., Minneapolis, Minn.

James Heber Lillard, post-graduate student, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 319.

Transfer of Grade

Norman W. Wilson, assistant professor of agricultural engineering, Alabama Polytechnic Institute, Auburn, Ala. (Junior to Associate Member)



Agricultural Engineering Digest

(Continued from page 55)

of the main applications of electricity to horticultural and allied work including power for cultivation and heat and light for the stimulation and control of plant growth.

The conclusion is that the use of electricity in horticulture is in its infancy. Electricity to supply bottom heat appears to have the best chance of commercial use; in fact, the electric hotbed is now being used on the continent.

The use of power for cultivation and the use of electric light for stimulating growth are in a rather different stage of development. Cultivating sets are in existence and work well. They do not appear as yet to produce an economic return for the capital cost involved. This is a case for reducing the cost of manufacture. Lighting produces pronounced effects on plant growth. Here again there is no evidence that the results justify the expenditure. More experimenting is required.

The Vertical Seed-Cotton Drier, C. A. Bennett (U. S. Department of Agriculture [Washington] Miscellaneous Publications 149 (1932), pp. 8, figs. 7).—This publication describes a simple installation which will dry sufficient seed cotton at a continuous rate to prevent interruptions in ginning caused by wide variations of weather and of moisture conditions in cotton.

In the process involved the damp seed cotton is treated with a continuous current of hot air, at the rate of from 40 to 100 cu ft of hot air for each pound of damp seed cotton, the damp seed cotton is exposed to the drying process for different periods, usually from 45 sec to 3 min, and the temperature of the drying air should preferably be between 160 and 200 deg for cotton handled during the early part of the ginning season. Temperatures as high as 225 deg have been used satisfactorily with late-season wet cotton. Tests have indicated that these temperatures have no unfavorable effect on the planting quality of the cottonseed.

Equipment required by this process includes a suitable drying cabinet or tower, a vacuum-wheel type of separator, two fans (generally), means for heating air, and the necessary cotton piping.

Cost of Pumping for Irrigation in Colorado, W. E. Code (Colorado Station [Fort Collins] Bulletin 387 [1932], pp 31, figs 12).—This bulletin reports data on the cost of pumping water for irrigation, obtained from a study covering a period of two years, under conditions that were representative of practice in the northern and southern parts of Colorado. In addition, data are reported on plant performance and cost of power resulting from tests made on plants in various pumping districts.

The results indicate that the ideal pumping plant is one which is of the correct capacity for the area involved and operating with a good load factor. The larger the area that can be served by a single plant the lower are the unit costs, and, conversely, these increase as the area decreases until a point is reached where certain component parts of the plant can not be economically reduced, causing a rapid rise in the unit costs.

It was found that water can be produced cheaply by a Diesel-engine plant, provided the load factor is good, although it requires full-time attendance. The total cost per acre-foot may be as low as 10 c with such a plant, whereas with a poor load factor the unit cost may exceed four times the cost for a gasoline engine. Between these limits were found the distillate-engine plants with a probable cost of about 15 c and the better class of gasoline-engine plants at about 25 c.

From the data obtained in this study and those obtained by tests on other plants, a fuel consumption per acre-foot for various types of engines is approximately as follows: Diesel, 0.25 gal; semi-Diesel, 0.30 to 0.35 gal; electric ignition with distillate, 0.35 to 0.40 gal; and for gasoline engines, 0.35 to 0.50 gal. The amount of fuel consumed will depend on the efficiency of the engine and the pump.

The importance of high load factor as regards engines, applies with equal significance to electric-motor-driven pumps operating on a sliding-scale rate.

The average cost per kilowatt-hour in the northern study was 2.87 c and 3.3 c in the southern study. The studies also showed that the total cost of water per acre under canals ranged between $5.37 and $11.41, wtih an average of $8.13. For engine-driven plants, the total cost per acre varied between $6.85 and $17.56, the average being $12.48, with the pumping lifts varying from 20.4 to 78 ft. The total cost per acre for the electric plants varied between $4.66 and $13.85, with an average of $9.76 for lifts between 22 and 46 ft. The studies indicate that the total lift for pumping plants should not exceed 40 ft.

[Agricultural Engineering and Irrigation Investigations at the California Station] (California Agricultural Experiment Station [Berkeley] Report 1931, pp. 50-53, 81, 82).—The progress results are very briefly presented of studies on farrowing houses for swine production, farm septic tanks, the effect of power interruptions on the hatchability of eggs set in electrically heated incubators, air measurement in electrically heated brooders, the reaction of insects to light, sterilization of fruit juices, efficiency and cost of operation of walnut dehydrators, general utility refrigerators, use of electricity for soil heating, steam sterilization of dairy utensils, dairy-manufacturing machinery, durability of fence posts, sugarbeet production machinery, equipment for insect eradication, frost alarms for orchards, oil filters, air cleaners, rice processing, bulk handling of grain, hay curing, fire hose, grape and cotton irrigation, water losses in rice irrigation, and irrigation requirements of and methods of applying water to citrus fruits.